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THE UNIVERSITY OF ALBERTA

SOIL PROFILE DEVELOPMENT ASSOCIATED

WITH DIFFERENT VEGETATIVE TYPES

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF SOIL SCIENCE

EDMONTON, ALBERTA

APRIL, 1967

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and
recommend to the Faculty of Graduate Studies for acceptance, a
thesis entitled "Soil Profile Development Associated with
Different Vegetative Types", submitted by James A. Dangerfield,
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ABSTRACT

Soil Development has long been known to be affected by the vegetation of an area. Grass is generally associated with the development of an Ah horizon, characteristic of the chernozemic soils. Forest vegetation is generally associated with the development of eluvial horizons common to podzolic soils.

This study was undertaken to determine the differences which occur within the organic and mineral horizons of profiles associated with different vegetative types and developed on parent materials similar in chemistry and mineralogy.

For the investigation sites with five vegetative types were selected. The organic horizons were sampled in triplicate in the spring and fall; a single mineral profile was taken at each site. Physical, chemical, mineralogical and biological analyses were conducted in order to characterize and evaluate differences of the organic and mineral horizons of the profiles.

Analyses indicate that chemical, mineralogical and micro-biological differences are evident in the profiles at different sites. Fungi are present in large numbers in pine and spruce litters, actino-mycetes in large numbers in aspen and spruce litters and bacteria in very large numbers in grass and balsam litters. A greater quantity of pentose, hexose and polyuronide sugar is present in the litter of pine than is found in other litters. The percentage of exchangeable calcium is lower in the profiles found under pine and spruce vegetation. Mont-morillonite, illite and iron translocation are evident in the profiles under pine and spruce vegetation while only montmorillonite transloca-tion is evident in the profile under aspen vegetation and no translocation

was evident under grass and balsam vegetation. Chlorite-montmorillonite interlayering is more evident under the pine vegetation.

All analytical data indicate the intensity of profile development to be: Bisequa Gray Wooded > Solodic Gray Wooded > Orthic Gray Wooded > Dark Gray > Gleyed Carbonated Dark Gray.

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I. INTRODUCTION

Examination of the soil zone map and the vegetation cover of the Peace River block reveals this area to be tree covered with the soils predominantly Gray Wooded. Upon examination of soils found within this area, it is noticed that under grassland vegetation Dark Gray Chernozems and Dark Gray Wooded soils predominate whereas under the more common tree cover the Gray Wooded profiles are more common. These are noticeable differences which occur between extremes in vegetation and suggest the possibility of less extreme changes of vegetation, such as tree species, producing more subtle changes within the soil body.

The mechanism of soil degradation under forest cover is not fully understood so it is difficult to assess the effect that the various forest covers will have. It is known that the effluent from the decomposing tree litter has a marked effect on the mineral constituents of the soil solum. Clay minerals, iron and aluminum may be mobilized. It is therefore feasible to postulate that litter from different tree species will produce different pedogenic effects depending upon the composition of the litter, the microbiological population and the nature of the material through which the effluent is leached.

The purpose of the project is to study and characterize the organic and mineral horizons of the profiles found under different vegetation types. For this investigation five main vegetation covers were selected within a confined area representing a single climatic zone. With this in mind, it was felt that this could best be accomplished by considering the following objectives:

(1) to characterize the organic horizons occurring under
     different vegetation as to biological, biochemical, micro-
     biological and mineralogical differences;

(2) to characterize the mineral horizons below these organic
     horizons as to chemical and mineralogical differences;

(3) to characterize the leachates from the organic horizons
     found under the different vegetation types as to chemical
     differences;

(4) to correlate and evaluate biological, biochemical and
     mineralogical variations found in the litter and the soil
     body developed under different vegetative types.

II. LITERATURE REVIEW

Dukachaev initially proposed that the soil was the result of the combined effect of soil forming processes which he stated as parent material, topography, time, vegetation and climate. Vegetation and climate were closely related and considered active factors of soil formation since climate strongly influences the type of climax vegetation as well as the associated flora and supplies energy for soils to develop. Blankmeisler (Lutz, 1948) has expressed the opinion that the influence of a specific forest stand on a soil is greatest in regions climatically favorable for the development of that vegetation type. More recent work (Kononova, 1961; Duchaufour, 1960) further substantiates the importance of the biological factor to soil development.

The biological factor includes the influence of plants and animals which eventually form part of the soil organic matter. Lutz (1948) states that substantial quantities of organic debris are returned to the soil by a leaf fall which exerts physical, chemical and biological influences. It is in the form of organic matter that plants and animals exhibit their greatest influence on soil genesis. Lutz (1948) further states that many workers have reported that weathering proceeds more rapidly in the vicinity of tree roots and thus assigns an indirect role to vegetation in soil development. Tyurin (Joffe, 1949) points out that pine with its surface rooting habit exhausts the bases from the horizon of eluviation more intensely than any other plant association, and it may be for this reason that podzolization effects are more strongly expressed under pine. Weathering around roots occurs but the profile develops downward into the soil body, indicating that the predominating effect in soil development is produced by the surface organic matter and its

subsequent leaching downward.

Early Russian scientists had linked the process of podzolization with organic matter. Sprengel, Ramann, Kekuchaev, Sibertzev, Glinka and others (Joffe, 1949) stressed the role of organic acids in the process of podzolization. In more recent years, various workers have stressed vegetation as a necessary requirement for the formation of a soil body.

Humic substances were first isolated from natural products by Arhard (Kononova, 1961). Berzelius (Joffe, 1949) was one of the first to carry out a systematic study of humic acids. He separated dark colored material, now known as humic acid, and light colored material, now known as fulvic acid. Schriener and Shorey (Joffe, 1949) subjected soil organic matter to many fractionation procedures and noted the variability of organic matter from different soils. Sprengel (Knonova, 1961) carried out chemical studies on humic acids and was responsible for noting many of the important properties of humic acids.

The present trend in soil organic matter, which began about the end of the last century, was the result of the development of two disciplines, microbiology and pedology. The works of Schriener and Shorey revealed the complex nature of humic acids. They established the existence of over forty separate organic compounds. By trying to divide humus into several separate chemical compounds, they overlooked the whole specific reserve of soil organic matter. During this period Millard (Kononova, 1961) presented the idea that soil organic matter was, in fact, synthesized products of simple plant decomposition.

Duchaufour (1960) has suggested that the type of soil organic matter is the principle factor in determining the genetic pathway

followed in soil development. This is stressed in his soil classification scheme based principally on genetic relationships as influenced primarily by the forms of organic matter. This is also illustrated in Alberta on a broad and general scale by the presence of chernozemic soils in grassland areas and podzolic soils in forested areas.

Vegetation of Alberta

Moss (1955) has compiled an extensive review of all the vegetation types of common occurrence in Alberta. He has divided Alberta into ten phytogeographic regions, these being: mixed prairie, main parkland prairie, Peace River parkland, boreal-grassland transition, boreal forest, boreal-Cordilleran transition, Cordilleran forest, subalpine forest, Montane forest, and alpine. This review is confined to the Peace River parkland and the pine, poplar and spruce vegetations of the northern boreal forest.

The Peace River Parkland (Moss, 1955) has been described as an Agropyron-Stipa-Carex community comprising three subtypes or faciations. These subtypes are listed as:

(a) Agropyron-Carex in low area.

(b) Stipa on dry slopes.

(c) Agropyron-Stipa on mesic sites.

Stipa faciations of xeric situations such as river valley slopes include porcupine grass (Stipa spartea var curtiseta); needlegrass (Stipa columbiana); wheat grass (Agropyron dasytachyum); june grass (Koeleria cristata); pasture sage (Artemisia frigida); and crocus (Pulsatilla ludoviciana).

The poplar vegetation of the northern boreal forest consists of two associations, these being: Populus tremuloides or white poplar and Populus balsamifera or balsam poplar. These stands are generally uniform in age and rarely exceed 120 years. The poplar association consists of five levels:

(a) taller trees which produce a continuous canopy and are the dominant species.

(b) smaller trees and larger shrubs which are generally poorly developed. Species generally common to both association are: woods rose (Rosa woodsii); prickly rose (Rosa acicularia); low bush cranberry (Viburnum edule); rose (Rubus idaeus); and willow (Salix spp).

(c) lower shrubs which are more or less obscured in the summer.

(d) taller herbs which form nearly a continuous stratum and are prominent during the later part of the growing season.

(e) lower herbs, these being the mosses and lichens. These form a locally continuous carpet which is generally very evident in the Populus balsamifera association.

Some of the herbs which are common to both associations of poplar may be listed as: dewberry (Rubus pubescens); aster (Aster ciliolatus); oregon vetch (Vicia americana); pine wintergreen (Pyrola asarifolia); wild strawberry (Fragaria glauca); fireweed (Epilobium augustifolium); western Canada violet (Viola rugulosa); marsh reed grass (Calamagrostis canadensis).

The balsam poplar association is generally found in the slightly wetter areas. This includes the species of shrubs such as dogwood (Cornus stolonifera); currant (Ribus spp.); honeysuckle (Lonicera involucruta); the herbs tall lungwort (Mertensia paniculata); horsetails (Equesitum spp.); coltsfoot (Petasites palmatus); and the mosses

(Hylocomium splendens and Aulacomnium palustre).

The white poplar found more commonly than the previously mentioned, includes the shrubs snowberry (Symphoricarpos albus); saskatoon (Amelanchier alnifolia); buffalo berry (Shepherdia canadensis); and the herbs dogwood (Cornus canadensis); and solmon seal (Maianthemum canadensis) in its association.

The white spruce (Picea glauca var albertina) association as described by Moss (1955) has four groupings or faciations. The two predominant are:

(a) Shrub-herb faciation. In this case the spruce are not crowded and there is usually a strong admixture of poplar and willow (Salix bebbiana). The shrub stratum consists of low bush cranberry (Viburnum edule); currant (Ribes spp.); prickly rose (Rosa spp.) and a luxuriant herb strata consisting of twin flower (Linnaea borealis var americana); dewberry (Rubus pubescens); tall lungwort (Mertensia paniculata); strawberry (Fragaria spp.); wintergreen (Pyrola spp.); fireweed (Epilobium augustifolium); marsh reed grass (Calamagrostis canadensis); dogwood (Cornus canadensis); bishop cap (Mitella nuda); violet (Viola renifolia) and coltsfoot (Petasites palmatus).

(b) Feather moss faciation. In this case the spruce is generally quite dense whereas the herbs and shrubs are sparse. Associated with this is an almost continuous mat of Hylocomium splendens, Calliergonella schreberi and other mosses with associated horsetails. The remaining two faciations are mixtures between these which occur because of differences in age, terrain, history and several other features. One species commonly associated with these faciations is

the common willow (Salix spp.).

The pine vegetation of the northern boreal forest of the area under study is a hybrid of the jack pine (Pinus banksiana) and lodge-pole pine (Pinus contorta var latifolia). In this association there are generally two faciations. They may be classified as:

(a) Pine-feather moss faciation. This is commonly associated with the more moist and shaded sites. This is characterized by mosses Hylocomium splendens and Calliergonella schreberi along with various higher plants such as twin flower (Linnaea borealis); wintergreen (Pyrola spp.) and dogwood (Cornus canadensis).

(b) Pine-heath faciation. This is usually found in the drier and more open part of the stands characterized by bearberry (Arctosta-phylos uva-ursi); blueberry (Vaccinium vitis-idaea); wild rye (Elymus innovatus); rice grass (Oryzopsis pungens).

Common to both faciations are several species such as alder (Alnus crispa); prickly rose (Rosa spp.); willow (Salix spp.) and solomon seal (Maianthemum canadensis).

Vegetation Effect on Climate

It has been stated by Lutz (1948) that forest vegetation creates conditions which would shift soil climate one to two degrees of latitude to the north. The forest vegetations make the area more humid and slightly cooler but any one climatic feature may vary independently depending upon the time of year and the vegetation in concern.

Kittredge (1948) stated that a difference in solar radiation reach-ing the ground is directly or indirectly the cause of differences in

temperature, atmospheric humidity, evaporation and transpiration.
A decrease in solar radiation is caused by an increase in:

(1) Percentage crown cover.

(2) Closeness of tree spacing.

(3) Tolerance of species.

(4) Progression of natural succession towards the climax.

There is generally a reduction in the annual temperature but
the degree of reduction depends upon the crown density and species.
Evergreens are more effective in the winter in reducing the daily
maxima and increasing the daily minima (6 degrees F. in January and
6.7 degrees in July) than deciduous trees. The species effect may to
some extent be reversed in the summer. The effect of the lower
maximum temperature (July minus 8 degrees F. and January minus 3
degrees F.) is a higher relative humidity. The high relative humidity
combined with an average wind velocity of one to two miles per hour
in forested areas (Kittredge, 1948) tends to reduce evaporation and
thus leave a more humid climate than in open grassland areas.
Evaporation in forested areas is reduced from 10 to 80 per cent of that
of the open area. Kittredge (1948) also stated that forest areas increase
rainfall by not over 3 per cent in temperate climates.

The lowering of maximum temperatures decreases the rate of
melting snow which may allow its presence six weeks after it has been
melted from surrounding areas. In combination with the litter layer
and the snow, which have very good insulating properties, the increased
minimum temperature and the depth of frost is greatly reduced. In

some cases it also advances the date of frost disappearance over that

of the open area, but, if there is excessive interception of snow by a

dense canopy, the frost disappearance is delayed.

It may be thus concluded that forest vegetation has a marked

effect on climate and this effect is influenced by tree species, density

of stand and age. This climatic effect will probably influence biological

activity and also the soil profile which subsequently develops.

Lutz (1948) has presented data on the leaf fall from various

vegetations. These values from different species and different loca-

tions were found to vary from 1730 to 3500 pounds of dry matter per

acre per year. Kittredge (1948) stated that leaf fall is a function of

stand and varies from 0.5 to 3.5 metric tons per year with species

differences being poorly defined. Stepanoff (Lutz, 1948) has reported

that the organic matter reaching the ground under Scotch pine could be

divided thusly: branches 8.6%, pine needles 49.4%, bark and cones

29.2%, leaves of underbrush 12.8%. Alway and Younge (Lutz, 1948)

reported that the litter from Jack and Norway pine in Minnesota was

found to be 1730 pounds per acre. Whitkamp and van der Drift (1961)

have reported that the leaf litter fall may fluctuate greatly depending

upon climate, disease and age of the vegetation. The more shallow

rooted species are more adversely affected by the climate.

Kendrick (1959) has presented data on the approximate time

material dropped on the surface will remain in each litter horizon

under a pine vegetation. These he states as:

(1) L layer - 6 months

(2) F_1 layer - 2 years

(3) F_2 layer - 7 years

He also stated that about 12 per cent variability may be expected since these are yearly fluctuations in time and quantity of leaf fall. This rate of decomposition is most definitely linked to the biological population.

Mineral Composition of Leaves of Various Vegetations

The mineral composition of leaves of different species and their litter is probably one reason for differences in iron movement and exchange cations under different vegetation. For example: Joffe (1949) states that since aspen leaves are very high in calcium and calcium humates are relatively insoluble upon dehydration, there is a good explanation for the accumulation of calcium in the Ah horizon under aspen vegetation.

Lutz (1948) has reported that the ash content of freshly fallen leaf litter varies from 3.08 to 15.16 per cent with the content from conifers generally being lower than that of deciduous vegetation.

RANGES OF NUTRIENT FLUCTUATION (LUTZ, 1948)

Mineral	% of Ash
K_2O	18.4 - 22.4
CaO	39.4 - 49.6
MgO	2.9 - 8.1
Fe_2O_3	1.1 - 3.1
P_2O_5	7.8 - 22.6

The deciduous tree litter is usually higher in all mineral nutrients.

NUTRIENT % OF TOTAL FOR LEAVES
(RALSTON & PRICE: FOREST SOIL, 1963)

	Ca	K	N	P
Pine	0.25	0.40	1.0	0.11
Oak	1.30	0.70	1.7	0.13

It has been stated by Lutz (1948) that plant materials high in nutrients decompose most readily.

Kittredge (1948) states that the percentage of CaO and nitrogen in the litter are usually correlated and both tend to be less under conifers than under deciduous trees. The percentage content of CaO, P_2O_5 and K_2O increase with depth and degree of decomposition from litter through duff and leaf mold.

Mina (1965) studied the leaching of calcium, magnesium, sodium, potassium and nitrogen from forest canopy and forest litter with lysimeters. He found that the major factors involved in the exchange of elements from the leaf top to the soil were species, precipitation and the growth habit of the plants. He also found that the leaching from the tree canopy brought an equal or greater quantity of the mineral nutrients to the soil than the leaf litter.

GROUPING OF % NUTRIENT CONTENT (KITTREDGE, 1948)

	CaO %	N %	P_2O_5 %	K_2O %
White Spruce	1.5 - 3.0 medium	1.1 - 2.1 high	0.15 - 0.3 medium	0.3 - 0.6 medium
Quaking Aspen	1.5 - 3.0 medium	0.4 - 0.8 low		
Jack Pine	0.3 - 1.5 low	0.4 - 0.8 low	0.05 - 0.15 low	0.05 - 0.3 low

Microbiological Populations

The number and kinds of bacteria present in a given soil are continually fluctuating. These fluctuations are of two types:

(1) daily or hourly, and

(2) seasonal.

It should be recognized that fluctuations in the population of soil organisms result in fluctuations of associated phenomena (Lutz, 1948).

Investigations in seasonal changes of bacterial numbers in forest soils in central and northern Europe have shown that the maximum numbers occurred during the summer and the minimum in the winter. A secondary maximum was reached either in the spring or fall. Chase and Baker (1954) compared biological numbers in an Ontario forest under three different vegetations. They found that bacteria and acti- nomycetes predominate under deciduous vegetation and fungi under coniferous vegetation.

PLATE COUNTS (CHASE & BAKER)

Sample	Bacteria	Actinomycetes	Fungi
Maple A_o	420,000	280,000	260,000
Hemlock A_o	350,000	460,000	1,310,000
Pine A_o	260,000	740,000	1,180,000

Ramann (Lutz, 1948) compared the biological population of a mull and mor humus layer of German forest, mor being the organic accumulation associated with severe podzolization and having very little well decomposed humus accumulation. In this case he found the fungal population greatly outnumbered the bacterial population.

Timonin (1935) compared the biological populations of some

Manitoba soils. A chernozem and a podzol developed under poplar

vegetation were compared over a summer period. From this and

similar experiments Timonin (1935) concluded that acidity decreases

the number of bacteria and actinomycetes in a soil body. Fungi

increase in numbers with increasing seasonal temperatures, whereas

bacteria and actinomycetes decrease during the warm months of July

and August with their numbers being highest in May and September.

PLATE COUNTS (TIMONIN)

	Bacteria	Actinomycetes	Fungi
Grass:			
May	49,150,000	4,800,000	26,000
June	37,830,000	2,430,000	28,166
July	19,200,000	3,825,000	46,750
August	19,000,000	3,250,000	60,127
Poplar:			
July	28,300,000	5,700,000	242,500

Katznelson (Lutz, 1948) has reported the bacterial popula-

tion is usually larger and the fungal population smaller for grassland

than for forest soils and in particular the podzols.

Whitkamp and van der Drift (1961) used such factors as cellu-

lose decomposition, lignin decomposition and CO_2 evolution as a

measure of the biological activities. They used loss of weight of the

pure compounds as a measure of the rate of decomposition. For the

mor humus layer they found that the rate of cellulose decomposition

was highest in the fall and spring and that the lignin decomposition was highest in the summer, but that for lignin there was little seasonal fluctuation. The high rate of cellulose breakdown in the fall and spring may be due to two factors:

(1)   This material is relatively easy to decompose and many bacteria possess this ability.

(2)   The highest bacterial numbers as reported by Timonin (1935) occur in the spring and fall.

Since lignin has been reported to be only broken down by the white rot fungi and fungal numbers are highest in the summer; indications are that its maximum rate of decomposition occurs during this time. One possible reason for the decrease in bacterial activity in the summer is the fact that the more easily decomposable cellulose has to a large extent been removed; thus supplies of energy are decreased. The fall leaf drop could thus cause a flush in bacterial activity. Whitkamp's and van der Drift's (1961) data for CO_2 evolution as a measure of biological activity shows a maximum activity in early September and therefore tends to support this conclusion. Biological numbers fluctuate as the result of many factors. Therefore, the interpretation of any data should be considered with reservation unless accumulated over a long period of time. Such things as variations in moisture, temperature, leaf fall, vegetation and wind velocities should be considered.

Microbiological Influence on Physical Properties

The biological population not only has an effect on the litter decomposition, but its by-products have a distinct effect on soil structure.

Little is known about the actual mechanism of soil aggregate formation except that it is strongly affected by the following (Martin et al, 1955):

(1) Bacteria and fungi.

(2) Gelatinous organic materials, gums, resins and waxes.

(3) Clay content.

Baver (1959) states that there is a high degree of correlation between the less than 0.005 mm. clay particles and the greater than 0.05 mm. size aggregates. Joffe (1949) states that no structure is possible without a critical quantity of clay, these being from 8 to 10 per cent. Some clays bond rapidly and slake when placed in water. This is due to the expanding nature of montmorillonite type clays and the explosive forces of entrapped air.

Martin, et al (1955) reports iron and aluminum oxides are very effective flocculating and cementing agents. This is especially true of tropical areas if accompanied by dehydration. These oxides may also provide a continuous matrix which bonds soil particles into secondary units by physical means.

Bacteria and fungi populations are factors which affect aggregation as well. This is predominantly through synthesis of various products but is also due to some extent to physical bonding.

Aspergillus niger and Azotobacter indicum are very effective in improving the soil aggregation (Martin, et al, 1955). This is probably due to the ability of these organisms to produce a large quantity of gelatinous slime of polysaccharide materials. Acton, et al (1963) reports that 20% of the microbial gum produced is of polysaccharide

material. He also concluded from his work that the polysaccharide content is likely responsible for, or is closely associated with the aggregation phenomena.

Bond and Harris (1964) have shown that filamentous micro-organisms persisted in both fine and coarse textured soils and that they played an important part in determining the physical properties of these soils. The ability of micro-organisms to form aggregates varies greatly and depends upon both the nature of the organism and the substrate available. Bond and Harris (1964) have shown that hyphae can exist in soil for a considerable time and still retain their strength.

Baver (1959) states that the organic matter content is more significant if the clay content is below 35 per cent. The organic matter effect is usually more noticeable upon addition of readily decomposable material. Leaf litter in the undecomposed state is effective in keeping frozen soil porous and permeable (Kittredge, 1948). Large additions of organic material are generally more effective than small additions.

The main effect of organic matter is probably a stabilizing one. This occurs through a weakening of strong cohesive bonds between clays and through particle linkage and is probably a physicochemical process (Martin, et al, 1955) which allows a distribution throughout the aggregate. The overall effect is to reduce swelling and the distinctive effect of entrapped air which occurs upon wetting.

The association of these aggregates affects many physical properties of the soil such as bulk density, pore space, permeability and available moisture holding capacity as well as many of the morpho-logical characteristics which are dependent to some extent on the soil

organic matter composition and content.

Organic Decomposition

Nikiforoff (1959) has approached the soil from a thermodynamic viewpoint. In this case the pedogenic processes are only a small segment within the larger thermodynamic geochemical cycle which includes the earth and sun.

The soil is an active pool of energy which is supplied by the sun and the internal heat of the earth. Like all thermodynamic systems the soil proceeds toward equilibrium. The soil thus serves as a turnstile through which pass endless swarms of atoms of excited matter. Most of these atoms participate in a series of consecutive reactions on route.

If a soil is near equilibrium then for every exergonic reaction there must be an equal endergonic reaction. Oxidation, hydration, the formation of carbonates and other salts are all exergonic reactions. The best known endergonic process in soil is the enrichment of soil in organic carbon.

Lutz (1948) has stated that the mature leaf consists of:

Cellulose	20 - 50%
Hemicellulose	10 - 28%
Lignin	10 - 30%
Tannin and waxes	1 - 8%
Protein	1 - 15%

depending upon the species and climate.

Very generally the decomposition of organic matter may be presented as the carbon cycle which is concerned with CO_2, its fixation and regeneration.

CARBON CYCLE (BEAR, 1964)
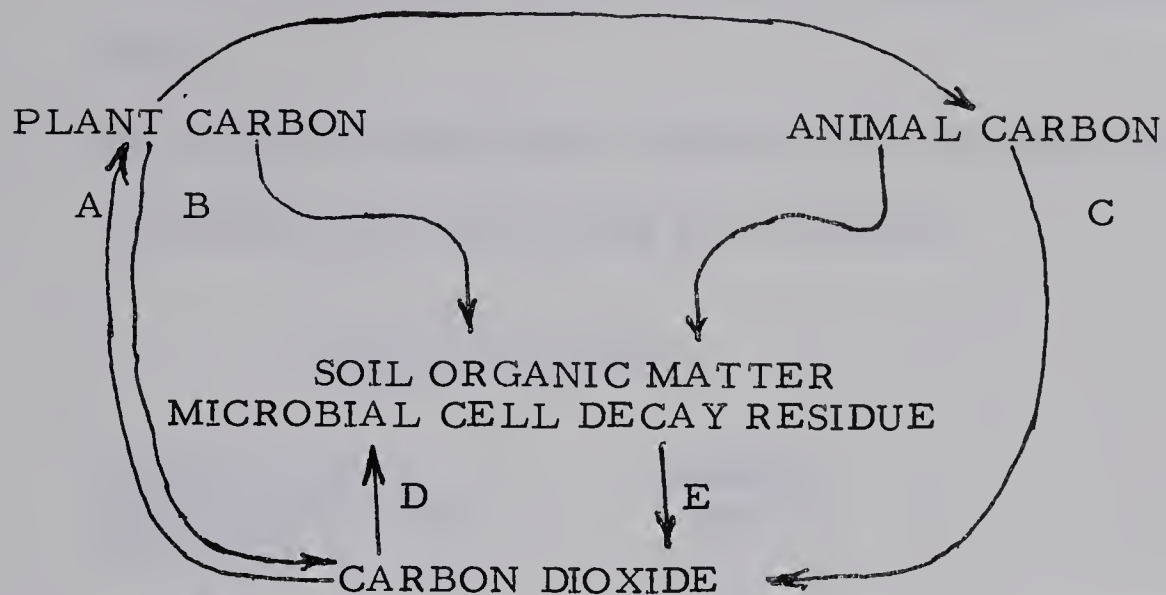
A. Photosynthesis
B. Respiration, plant
C. Respiration, animal
D. Autotrophic micro-organisms
E. Microbial Respiration

The central portion of the carbon cycle may be represented more specifically by the scheme shown on the following page.

A more specific study of the breakdown reveals cellulose, hemicellulose and protein to be relatively easy to decompose. Proteins are very quickly broken down but they are continually resynthesized as a part of microbial protoplasm so that their content may actually rise upon addition of organic matter to the soil.

Fungi, bacteria and actinomycetes all contain member species capable of cellulose and hemicellulose breakdown. The breakdown is carried out in three stages (King, 1961):

(1) Disaggregation. This involves breaking of molecules into long chains through the presence of an extracellular enzyme.

(2) Extracellular hydrolysis. This consists of a random hydrolysis

of glycosyl bonds or the successive removal of cellobiosyl

units.

(3) Intracellular metabolism involves the breakdown of the

cellobiose units into single glucose units.

PLANT & ANIMAL

CELLULOSE   LIGNIN
HEMICELLULOSE   TANNIN
PROTEIN

CO_2 CO_2

H_2O MICROBIAL   MICROBIAL
NH_3 DECOMPOSITION   DECOMPOSITION H_2O
                                  or NH_3
                                  MODIFICATION

MICROBIAL PROTO-
PLASM & METABOLIC
BY-PRODUCTS
                                  MODIFIED
                                  LIGNIN &
                                  AROMATICS

AROMATIC   AMINO ACID
STRUCTURE   PROTEINS

                     HUMUS

MINERALIZATION
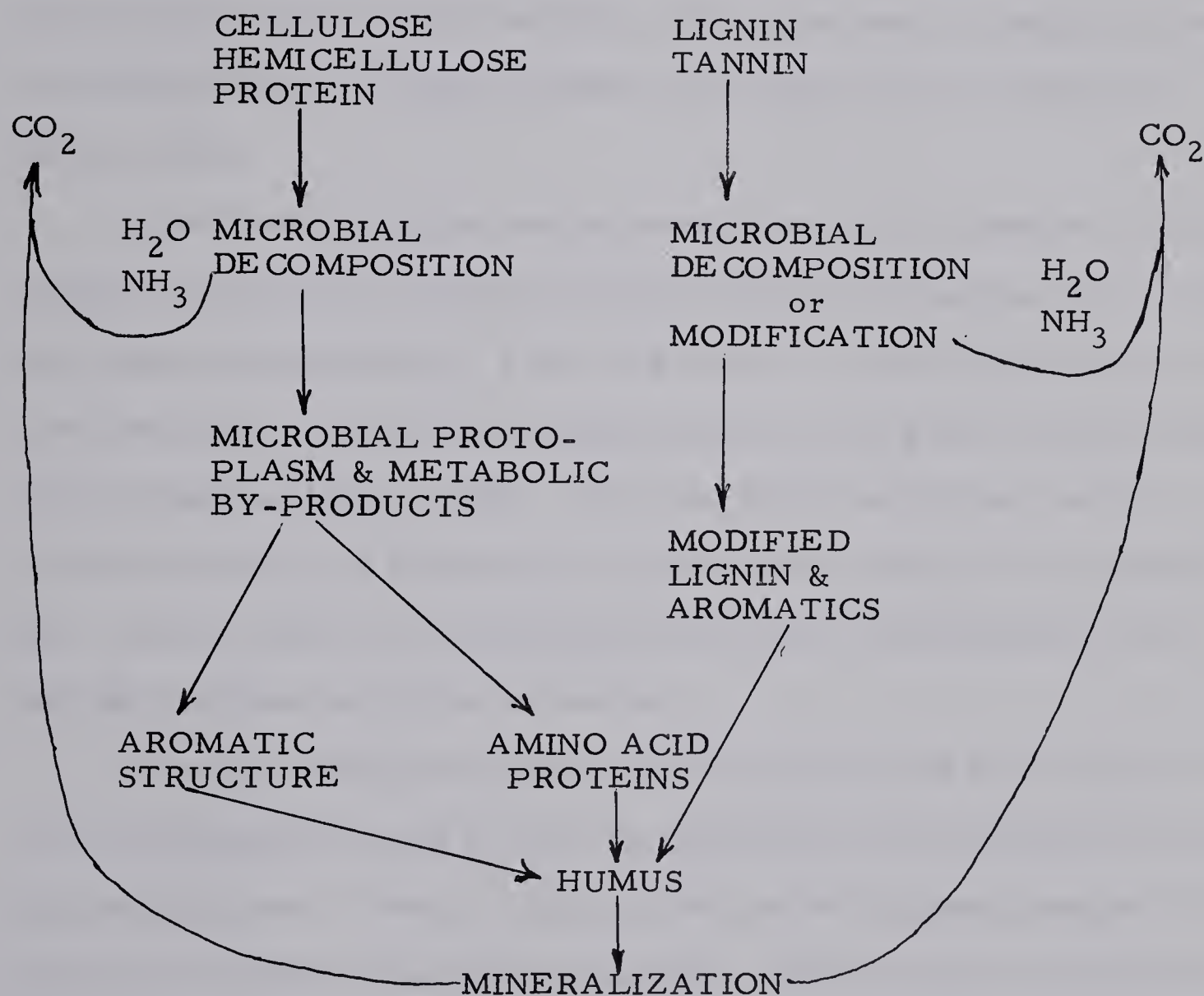
Lignin is the most resistant of the materials produced. This

material slows breakdown through its own resistance to decomposition

and by acting as a physical barrier to the movement of extracellular

enzymes to the more easily decomposable materials. Only the

commonly named white rot fungi are capable of lignin decomposition at the initiating level.

Lignin is composed of phenyl propane units with attached methoxyl and hydroxyl groupings linked through several different types of bonds (Nord, 1964). The basic building block of phenyl propane will vary with the vegetative species. Grass lignin is composed predominantly of p-coumaryl alcohol with the majority of the tree species being composed of coniferyl alcohol. Sinapyl alcohol is the basic unit for pine lignin (Nord, 1964).

The first step in the breakdown of lignin is the cleavage of ether linkage and the loss of methoxyl groups probably through the presence of the enzyme phenyloxidase. From this stage, the material is further oxidized and broken down or else polymerization occurs and a form of humic acid is produced (Flaig, 1964). After the initial breakdown reaction, several bacterial and actinomycete species may continue the decomposition. At any stage in the subsequent breakdown, polymerization may occur with the resultant formation of humus.

Bremner (1954) states that the material derived from plants in the soil is drastically altered in the kind and position of the peripheral groupings on the aromatic ring. A large portion of the hydroxyl groups are absent and carboxyl groups have appeared. There is also a substantial decrease in methoxyl group content.

Effect of Organic Matter Decomposition on Soil Development

The decomposition has a very definite effect on the chemical properties of organic matter. Lutz (1948) reports that there is an

increase in the cation exchange capacity. This is due to the replace-
ment of the hydroxyl and methoxyl groups with carboxyl groupings
(Bremner, 1954).

Gessel and Balci (Youngberg, 1963) have reported that there is
a decrease in carbon content with increased decomposition and a slight
increase in the total nitrogen. This results in a narrowing of the carbon
to nitrogen ratio. Alexander (1961) also reports a narrowing of the
carbon to nitrogen ratio but that there is a decrease in nitrogen as well
as carbon during the decomposition. Joffe (1949) states that the greater
the degree of decomposition the lower the per cent carbon and thus
explains the increase in carbon content progressively from chernozem
to podzol.

Knonova (1961) states that the oxygen to hydrogen ratio becomes
wider as decomposition occurs.

Lutz (1948) has reported after Watson (1930) that the content of
lignin increases in the more decomposed material, whereas the more
readily decomposable materials decrease. This is simply due to the
relative rates of decomposition.

Kononova (1961) states that the degree of condensation of the
aromatic ring of humic acids increases in passing from podzolic to
chernozemic soils. This would result in a greater mobility of organic
matter in podzolic soils than in chernozems.

Biogeochemical Effects

It is difficult to separate the microbiological decomposition
products from the organic matter of the soil when weathering, mineral

movement and organic movement is considered within the soil solum. For this reason all are considered together.

Voight (Youngberg, 1963) has studied the mobilization of potassium. He found Aspergillus niger capable of releasing from 0.5 - 1.5 mgm. of potassium per gram of tissue from biotite, muscovite and microcline in that order of ease of release. He also found that this fungi produced large quantities of gluconic acid which is also capable of bringing about the mobilization of potassium from these minerals. Other workers have shown that Ketogluconic acid dissolves silicates including feldspars and micas.

Evans (Hallsworth and Crawford, 1965) reports the identification of a quartz calculus derived from a kidney. This illustrates that amino acids and enzymatic reactions dissolve insoluble silicates with remarkable facility and also control the subsequent recrystallization of those inorganic substances into minerals.

Harington (1962) has associated the asbestos mineral croccidolite with biological processes through the identification of nine amino acids and 3, 4-benzopyrene associated with it. Maybe it is possible that nucleic acids and enzymes are solubilizing agents in and during the formation of sediments. When pure quartz sand was allowed to settle in M/5, Na - A.T.P. during daylight, it was found upon examination that this material had been converted to quartzite (Hallsworth and Crawford, 1965). The silica released from solution had recrystallized into a secondary quartz cement. This indicates that nucleic and amino acids may play a role in sediment cementation. Similar quartz clustering is commonly noted in woodland and peat land.

When sodium silicate was dissolved in Na - A.T.P. and allowed to stand under a cover glass, a fibre-radiate development of sodium alumino-silicates emerged which have the optical properties of low temperature feldspars (Hallsworth and Crawford, 1965).

This discussion has shown that biological products are capable of assisting in the mobilization as well as formation of certain minerals.

Humus Movement

Humus movement downward in the soil profile may occur to such an extent in some cases that it meets the criteria for a Bh or a Bfh horizon. This is considered part of the podzolization process. The formation of Bfh horizons may be due partly to the downward movement of sesquioxides in organic complexes with a subsequent immobilization. Generally, however, this will not result in the formation of a Bh horizon. Stobbe and Wright (1959) through morphological observations, suggest that a large percentage of the organic matter moves to the B horizon in solution and colloidal suspension. They have observed large masses of dark organic matter passing through the Ae in a wavy manner after a rain. The material is filtered out where the concentration of humus and sesquioxide occur. Periodic drying stabilizes the organic matter against further movement.

Sesquioxide Translocation

As an inorganic cation. The close connection between movement of sesquiozides and the decomposition of organic matter has long been recognized. It has been suggested that the acidity created by the decomposition products of organic matter brings about solution of

sesquioxides with a subsequent deposition in lower horizons due to a
higher pH (Deb, 1950). Since the solubility of ferric iron at a pH
above 3.5 is negligible and the pH of podzols is seldom that low, move-
ment in the inorganic form is unlikely (Stobbe and Wright, 1959).

As a sesquioxide-humus sol. It has been suggested that
hydrated free oxides are transported as negatively charged humus
protected sols (Aarino, 1913). Humus may carry from three to ten
times its own weight in iron oxide varying with different organic frac-
tions (Deb, 1950). If this theory is to be accepted, it is necessary to
assume either microbial decomposition or a divalent cation causing
precipitation in the B horizon. It is most likely that a microbial
mechanism is operative since the supply of divalent cations is very low
in a podzol (Deb, 1950).

Stobbe and Wright (1959) have discounted the theory of forma-
tion, movement and deposition by isoelectric weathering since this
would require a significant pH gradient downward in the profile, a
condition which does not exist in many podzols.

As soluble metal-organo complexes. The most acceptable
mechanism for sesquioxide movement is as soluble metal-organo
complexes. The compounds can exist as complex ions or a chelate.
Many workers (Gallagher and Walsh, 1943; Jackson and Sherman, 1953)
have suggested that relatively simple organic acids complex sesqui-
oxides. Acquaye and Tinsely (Hallsworth and Crawford, 1965) have
reported that citric acid causes silicate, aluminum and iron to remain
soluble up to a pH of almost 8 by forming complexes with the metals.

The Russian workers, Alexandrova (1954) and Kononova (1956) suggested that sesquioxides may be complexed with humic acids or humates while Yarkov (1956) attributed the complex formation to fulvic and other low molecular weight acids with ferrous and not ferric compounds. Yarkov (1956) suggested that periodic anaerobic conditions allow the formation of the ferrous compounds.

Aqueous extracts of many vegetative materials have the ability to reduce iron and then complex it into a stable form (Bloomfield, 1953, 1954; Schnitzer and Delong, 1955). The reduction of ferric iron occurs even under anaerobic conditions. The reduction of iron and solution of the ferric oxide has been attributed to the action of carboxylic acids and polyphenols with reduction being affected primarily by the latter compounds (Bloomfield, 1957).

Bloomfield (Hallsworth and Crawford, 1965) reports that the activity of the agents for mobilizing iron are the greatest in the fresh leaf extract of deciduous species. The probable difference which reduces this effect in the field is the oxidation of the polyphenols. The species least affected by this oxidation are those associated with podzol formation: spruce, pine and fir.

The method of deposition of the sesquioxides from complexes is uncertain. Yarkov (1956) believes that the deposition is due to reoxidation of the mobile ferrous compound and the destruction of the organo-complexes by micro-organisms. Similar suggestions have been made by Deb (1950). Crawford (Hallsworth and Crawford, 1965) has presented data which support this idea. By leaching a ferrous leaf extract through sterilized and unsterilized soil columns, he found that the ferrous

material could be leached through the sterilized column but not the unsterilized column.

Present research suggests that naturally occurring chelating substances play a large part in sesquioxide movement. Schnitzer and Delong (1955), as well as Swindale and Jackson (1956), suspect chelation in podzols but have not proven it. Profiles similar to those of podzols were produced by Wright and Levick (1956) and Atkinson and Wright (1957) by leaching a column of calcareous sand with E. D. T. A. Wright and Schnitzer (1963) produced a similar profile by leaching a calcareous sand column with fulvic acid. This led them to assume that the fulvic acid is the dominant ligand affecting sesquioxide movement in the podzolization process.

Fulvic acids consist of an aromatic "nucleus" to which carboxyl, hydroxyl and carbonyl groups are attached (Wright and Schnitzer, 1963). Stobbe and Wright (1959) have reported that 60% of fulvic acids are composed of functional groups of this nature.

Wright and Schnitzer (1963) believe that the movement occurs in the form of a water soluble multidentate chelate with metals such as iron, aluminum and calcium. The precipitation of the metal-organic complex lower in the profile is caused by further reaction with the same metals and by extremely small amounts of ionic calcium and/or magnesium. Stobbe and Wright (1959) have shown that the ferrous organic complex can be precipitated with a concentration of 0.13 ppm. of calcium and/or 4.5 ppm. of magnesium. Aluminum organic complexes are less soluble than iron but they also are less susceptible to precipitation by calcium and magnesium. Bloomfield (Hallsworth and Crawford, 1965)

states that successive treatments of a solution of iron-leaf extract complex with ferric oxide decreases the amount of iron in solution giving a curve which is the inverse of the distribution in the podzol profile. This suggests a possible connection with deposition of iron and organic matter in the illuvial horizon of a podzol.

Bloomfield (1955 b) noticed that drying and/or aeration brings about precipitation of sesquioxides. Bloomfield (1955 a) also noted that the immobilization of sesquioxides is associated with the sorption of the complexes on the mineral soil material. The reprecipitation process is not fundamentally one of reoxidation although it is favored by oxidizing conditions.

Translocation of Clays

Duchaufour (1960) has found that clay may be moved by organic matter without undergoing chemical change. This mechanical transport brought about by a complexing with organic matter he calls "lessivage" as opposed to podzolization which require chemical weathering and transport of the weathered products.

Several persons, Wright, Leahey and Rice (1959); Pawluk (1960, 1961); St. Arnaud and Mortland (1963), have reported clay movement in the formation of the textural B horizon. Clays are probably moved by a leaching action of the acid decomposition products of forest vegetation (Pawluk, 1960). Duchaufour (1960) feels that the water soluble organic materials favor and maintain dispersion of the clay and thus are one of the main factors in "lessivage." He feels that gravitational water is an essential agent in that it carries the

dispersed complex mechanically.

Lynch and Graveland (1962) have studied the clay-organic bond of some chernozemic and solonetzic soils. They found the organic material was more strongly bonded in the lower than in the upper horizons. This material tended to be alkali soluble and acid insoluble indicating it to be predominantly humic acid.

Brydon and Sowden (1959) studied the nature of the clay-humus complex of chernozemic and podzolic soils. The humate fractions contained a concentration of fine grained montmorillonite. Since the Bt horizon usually contains an accumulation of fine clay, this is a good indication that clay movement occurs as an organic complex.

Fridland (1958) suggests three methods by which the clay minerals may be stabilized in suspension:

(1) Organic materials.

(2) Colloidal silica.

(3) Adsorbed hydrogen on the surface of the clay micelle.

Since there is often an enrichment of silica in the textural horizon, Fridland (1958) believes the mechanism involving colloidal silica should be favored.

A method by which silicate clay may be translocated from the A to the B horizon at relatively high pH has been proposed by Pallmann (1943) as quoted by Cline (1949). As evidence that such a process may be operative it can be shown that:

(1) clays in slightly acid Ae horizons of Gray Brown Podzolic soils of New York go into stable suspension in water;

(2) those of weakly alkaline or neutral B do not; and

      (3) suspension from the Ae are flocculated by addition of
           suspension from the B horizon.

Clay-Organic Bonding

Many authors have classified clay organic reactions according

to the nature of the organic species involved. A typical system is

presented below:

    (1) Organic anions. Clay minerals react with a variety of
        organic anions such as phenolates, carboxylates and
        sulfonates through the exposed octahedral aluminum at
        the broken clay edge. Van Olphen (1963) states that tan-
        nates and simple phenols are capable of peptizing clays.
        In order for phenols to be effective, these substances
        must contain at least three phenol groups in a molecule,
        two of which should be adjacent.

    (2) Organic cations. This reaction produces an adsorption at
        the edge of the clay surface. The organic cations adsorbed
        in this way are the amines, quaternary ammonium salts or
        quaternary bases. Amine groups in acid conditions pick up
        hydrogen ions to form NH_3^+ groups which cause the organic
        molecule to behave as a cation adsorbed on the clay surface.

    (3) Organic polar molecules. The functional groups of organic
        molecules such as carboxyl, hydroxyl and sulfonic acid all
        contain atoms which are fairly electronegative in nature and
        thus when attached to aliphatic or aromatic nuclei tend to
        cause the formation of dipoles. Attraction between positive
        and negative sites will result in the formation of clay organic
        complexes.

    (4) Reaction with polyelectrolytes. Polyelectrolytes are long
        chains with groups that will ionize along the entire length of
        the chain. Polyions may form when these groups ionize with
        the resulting ions being polycations and/or polyanions.
        Proteins are such substances.

Hendricks (1951) found that the adsorbed organic ions tended to

orientate themselves between the layers in such a manner as to cause the

least expansion of the layers. It has been shown that more than one

molecular layer may be adsorbed on the basal surfaces of the montmorillo-

nite planes. Jordan (Van Olphen, 1963) has determined the c-axis spacing

of montmorillonite from Wyoming bentonite with aliphatic amines of increasing chain length. It was found that as the number of carbon atoms in the amine chain increased, there was a definite series of steps in which the basal plane spacing increased by increments of four angstroms. This is about the van der Walls thickness of a methyl group. Jordan took this as an indication that the chains lie flat along the clay flake surface with the "zig-zag" carbon chains parallel to the plane of the mineral. Further data, supporting the adsorption between lattice planes, are given by the reduction in the water adsorbing properties as the basal surface of the mineral is coated with organic ions or molecules. It has been found that the greater the reduction in water adsorbing capacity, the larger the size of the organiz molecule.

Kohl and Taylor (1961) have investigated hydrogen bonding between carboxyl groups and Wyoming bentonite. They used infrared analysis and the shift of the carboxyl adsorption band to a longer wave length as an indication of hydrogen bonding. They suggest hydroxyl groups exposed at the broken edge of the clay particles could be the reactive sites. They also suggested polyuronides may be bound by hydrogen bonding.

Summary of Literature Review

Nikiforoff (1959) has presented the soil as a thermodynamic system. He also states that the best known endergonic process is the enrichment of soil in organic carbon. This literature review has dealt with accumulation of organic carbon as influenced by vegetation and its

subsequent effect on the soil solum.

Various workers have stated the importance of organic matter in soil development. The type of organic matter is influenced by vegetative species. Different species have an effect on the micro-climate. Deciduous species tend to lower the maximal summer temperature more than the evergreen species whereas the reverse is true during the winter months. This effect does, however, depend on the tree and crown density. Evaporation, wind velocity and relative humidity are also noticeably affected if forest vegetation is compared to grassland vegetation.

The vegetative species and the factors which it controls have a profound effect on the seasonal fluctuations of the biological popula-tions. Fungi tend to predominate under more acid conditions and have their maximal activity during the period of increased temperature. These conditions are most favored under an evergreen vegetation. Quantity and time of leaf fall also influence the population fluctuation. The species generally determines the length of time this litter will remain before being completely decomposed, evergreen species gener-ally persisting for the greatest length of time.

The biological population and the resultant decomposition products have a definite effect on the physical properties of the soil. It has been stated that the organic matter is very important in control-ling aggregate formation if the clay content is below 35 per cent. Generally, the uronic acid content is correlated with good aggregation. Certain microbiological species are very effective in producing aggre-gate-forming compounds; thus vegetative conditions control aggregation

to some degree. The most marked physical effect of the leaf litter is the maintenance of porosity in the frozen state.

Decomposition of the leaf material by the biological population generally results in an initial decrease in molecular size. Associated is an increase in cation exchange capacity and a decrease in methoxyl content. In most cases, there is a decrease in the percentage carbon and a narrowing of the carbon to nitrogen ratio. The percentage of slowly decomposed materials increases through a negative accumulation as decomposition occurs.

The decomposition products have been indicated as playing a role in the weathering of various minerals. Potassium release has been aided by the presence of α-Ketoglutaric acid and quartz solubility is greatly increased in the presence of a very dilute solution of A.T.P. As well as affecting the mineral weathering rate, movement of iron, aluminum and clay is influenced through a chelating, complexing or dispersing effect. This ability varies with species, deciduous vegetation possessing the greatest ability. The chelating ability of fresh leaf is very rapidly destroyed in the deciduous litter, whereas it is maintained over a longer period of time with the evergreen. Precipitation of solubilized chelates may be caused by microbiological weathering or the presence of very weak concentrations of calcium and/or magnesium.

In conclusion, evidence available in the literature bears out the importance of organic matter and vegetation in the formation of the soil solum.

III. MATERIALS AND METHODS

Materials

The area of northern Alberta, in the Peace River region where the soils under study are found, (see Figure 1) is characterized by a subhumid climate. The annual precipitation is approximately 12 to 15 inches with a mean annual temperature of about 33. 7° F. The highest amount of precipitation is received during the summer months with June being generally very dry. About 55 per cent of the rainfall is received in less than 0. 10 inches per day and 90 per cent in rates less than 0. 50 inches per day. The average wind velocity is about 6.8 miles per hour. (Department of Transport, Meteorological Reports)

Generally, the native vegetation consists of mixed tree cover in which aspen poplar (Populus tremuloides) predominates. Special variations within confined areas are found throughout and thus form the basis for this study. The vegetation types which were considered for study in this project were:

(a) Aspen Poplar (Populus tremuloides)

(b) Balsam Poplar (Populus balsamifera)

(c) Grass. This was a mixture common of the Stipa faciations of xeric situations, such as river valley slopes. (Stipa spartea var curtiseta)

(d) Pine (a hybrid of Pinus banksiana and Pinus contorta var latifolia)

(e) Spruce (Picea glauca)

The five vegetative types mentioned above were used as a means of selecting sampling sites. These experimental sites were located in an area north from the Miekle River in 6-94-22-W5th to Twin Lakes in

the northwest corner of 97-22-W5th. (Figure 1) The Profiles found at the five different sites were classified as being in the Chernozemic and Podzolic orders as outlined in the Canadian Classification system. Samples of the organic horizons were collected in triplicate at each site in September, 1964 and May, 1965 in order to evaluate possible fluctuations in the biochemical properties occurring between spring and fall. The mineral profile at each site was sampled on a horizon basis in September of 1965. Lysimeters were set out in the summer of 1965 to collect leachates at each of the sites, but due to lack of rain during that summer and spring flooding in 1966, no collections were possible until the fall of 1966.

Tables I to V give profile descriptions at each site.

Methods

Upon arrival at the laboratory, the organic samples were "quartered" for pH determination. All samples were then spread out and air dried. The organic samples were ground with a Wyllie-Mill and the mineral samples were ground in the steel-roller mill to pass a 2 mm. sieve. Prior to grinding, the mineral samples were "quartered" and a portion was ground with mortar and pestle to avoid iron contamination. A portion of each sample was taken for pH and hygroscopic moisture determination.
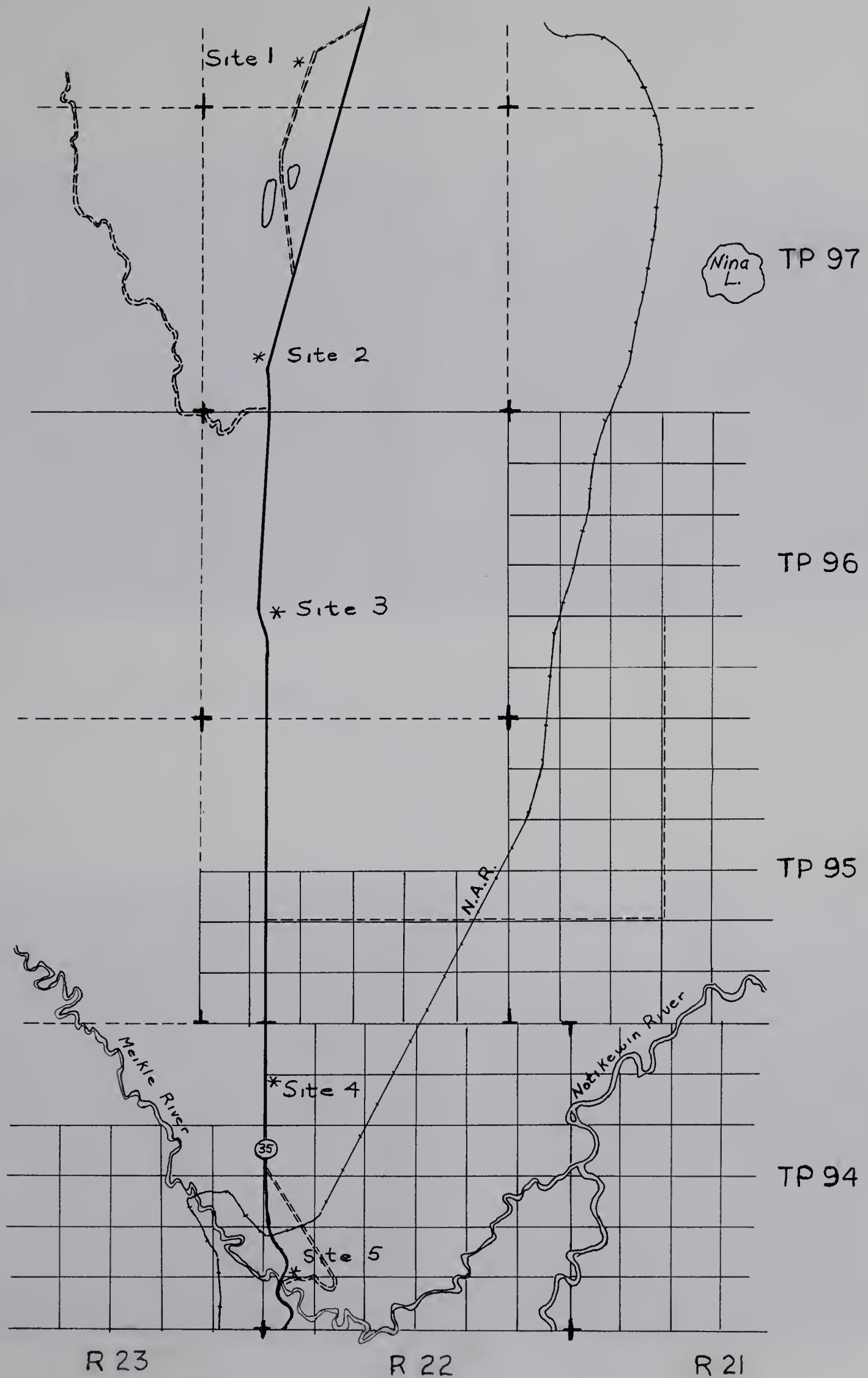
Figure 1   Map of sampling area

Plate 1

Site 1. Balsam Vegetation

Site 2. Pine Vegetation

Site 3. Aspen Vegetation

Site 4. Spruce Vegetation

TABLE I

PROFILE DESCRIPTION OF SITE 1.

LOCATION: SW 4 - 98 - 22 W5

VEGETATION: Balsam (Populus balsamifera)

CLASSIFICATION: Gleyed Carbonated Dark Gray

Horizon	Depth	Color* Dry	Color* Moist	Texture	Structure**	Consistence**
L	1-1/2"				undecomposed leaf	
F	2"				very weak leaf structure	
H	3"				fluffy, loose	
Ah	4"	dark grayish brown 10 YR 3/2 - 4/2	very dark brown 10 YR 2/2	L	crumb	friable
Bkgj	10"	pale brown 10 YR 6/3	dark brown 10 YR 4/3	L	medium sub angular blocky	friable
BCkgj	6"	grayish brown 10 YR 5/2	dark grayish brown 10 YR 4/2	L	medium sub angular blocky	friable
Ckgj1	6"	grayish brown 10 YR 5/2	dark grayish brown 10 YR 4/2	SL		friable
Ckgj2	+ 26"	pale brown 10 YR 6/3	grayish brown 10 YR 5/2	CL		firm

* Munsell colors

** Canadian Soil Classification Scheme

TABLE II

PROFILE DESCRIPTION OF SITE 2.

LOCATION: SW 8 - 97 - 22 W5

VEGETATION: Pine (Hybrid of Pinus banksiana & Pinus contorta var latifolia)

CLASSIFICATION: Bisequa Gray Wooded

Horizon	Depth	Color* Dry	Color* Moist	Texture	Structure**	Consistence**
L F	- 1/2" 1"				undecomposed leaf strong leaf structure with weathered appearance	
Ae1	1"	gray 10 YR 6/1	dark grayish brown 10 YR 4/2	SL	granular	very friable
Bfj	4"	light yellowish brown 10 YR 6/4	dark brown 7.5 YR 4/4	L	granular	very friable
Ae2	5"	light yellowish brown 10 YR 6/4	dark yellowish brown 10 YR 4/4	SiL	small sub angular blocky	friable
Bt	7"	light yellowish brown 10 YR 6/4	dark yellowish brown 10 YR 4/4	L	medium sub angular blocky	firm
IIC	+ 19"	brownish yellow 10 YR 6/6	dark brown 7.5 YR 4/4	LS		loose

*   Munsell colors
** Canadian Soil Classification Scheme

TABLE III

PROFILE DESCRIPTION OF SITE 3.

LOCATION: SE 17 - 96 - 22 W5

VEGETATION: Aspen Poplar (Populus tremuloides)

CLASSIFICATION: Orthic Gray Wooded

Horizon	Depth	Color* Dry	Color* Moist	Texture	Structure**	Consistence**
L	1"				undecomposed leaf material	
F	- 3/4"				very weak leaf structure	
H	- 1/4"				fluffy, loose	
Ae	6-1/2"	very pale brown 10 YR 7/3	yellowish brown 10 YR 5/4	SL	medium platy	friable
AB	3-1/2"	pale brown 10 YR 6/3	dark brown 10 YR 4/3	L	small sub angular blocky	friable
Bt1	7"	pale brown 10 YR 6/3	dark brown 10 YR 4/3	CL	medium sub angular blocky	firm
Bt2	4"	grayish brown 10 YR 5/2	dark brown 10 YR 4/3	CL	small blocky	firm
BC	9"	grayish brown 10 YR 5/2	dark grayish brown 10 YR 4/2	CL		very firm
C	+ 30"	grayish brown 10 YR 5/2	dark grayish brown 10 YR 4/2	SiCL		very firm

* Munsell colors

** Canadian Soil Classification Scheme

TABLE IV

PROFILE DESCRIPTION OF SITE 4.

LOCATION: NW 30 - 94 - 22 W5

VEGETATION: White Spruce (Picea glauca)

CLASSIFICATION: Solodic Gray Wooded

Horizon	Depth	Color* Dry	Color* Moist	Texture	Structure**	Consistence**
L	- 3/4"				undecomposed leaf and moss growth	
F	1-1/2"				leaf structure evident	
Ae	1-1/2"	gray 10 YR 6/1	grayish brown to dark grayish brown 10 YR 4/2 - 5/2	SiL	medium platy	friable
AB	1-1/2"	light gray 10 YR 6/1 - 7/1	grayish brown 10 YR 5/2	SiL	coarse sub angular blocky	firm
Btnj1	3"	gray 10 YR 5/1	dark grayish brown 10 YR 4/2	HC	medium blocky	very firm
Btnj2	6"	gray 10 YR 5/1	very dark grayish brown 10 YR 4/2	HC	coarse sub angular blocky	firm
BC	7"	gray 10 YR 5/1	very dark gray 10 YR 3/1	HC		firm
C	+ 22"	gray to dark gray 10 YR 4/1 - 5/1	very dark gray to very dark grayish brown 10 YR 3/1-3/2	HC		firm

*Munsell colors
**Canadian Soil Classification Scheme

TABLE V

PROFILE DESCRIPTION OF SITE 5.

LOCATION: NW 6 - 94 - 22 W5

VEGETATION: Grass (Stipa faciation)

CLASSIFICATION: Dark Gray

Horizon	Depth	Color* Dry	Color* Moist	Texture	Structure**	Consistence*
O.M. Sod	- 1/2" 1"				fluffy, loose firm, matted root area	
Ah	4"	very dark grayish brown 10 YR 3/2	very dark brown 10 YR 2/2	SiC	granular	friable
AB	3"	gray 10 YR 5/1	dark gray to very dark gray 10 YR 3/1 - 4/1	SiC	small sub angular blocky	friable
Btj	5"	grayish brown 10 YR 5/2	very dark grayish brown 10 YR 3/2	HC	coarse blocky	firm
BC	3"	grayish brown 10 YR 5/2	very dark grayish brown 10 YR 3/2	C	medium sub angular blocky	firm
IIC	+ 15"	grayish brown 10 YR 5/2	dark gray 10 YR 4/1	CL		firm

* Munsell colors
** Canadian Soil Classification Scheme

Physical Analysis

Mechanical analysis of the soil samples was determined by the pipette method outlined by Toogood and Peters (1959) and the fine clay content was determined by evaporating an aliquot separated from the total clay fraction by centrifugation as outlined by Baver (1959). Salts were removed with repeated washing; organic matter with H_2O_2; and calcium carbonate with the addition of 0.1 N HCl.

Hygroscopic moisture was determined by drying samples for 16 hours at $105^\circ C$.

Chemical Analysis

pH values were determined on a saturated soil paste as outlined by Doughty (1941) using a Beckman model zeromatic pH meter.

Total nitrogen of the organic and mineral horizons was determined by the Kjeldahl-Wilfarth-Gunning method (A.O.A.C. 1955). The catalyst used was HgO (0.41 gm.), $CuSO_4$ (0.08 gm.) and K_2SO_4 (9.9 gm.) packaged in a polyethylene bag and sold commercially as Kel-pak. The ammonia was collected in a 4 per cent H_3BO_4 solution as suggested by Meeker and Wagner (1933) and titrated against standardized H_2SO_4.

Total carbon content was determined by measuring the amount of total carbon evolved as CO_2 with the Leco dry combustion method. The samples were ground to pass a 60 mesh sieve and 0.0200 - 0.0500 gm. of this material was weighed and placed in an induction furnace. CO_2 evolved was measured manometrically.

Calcium carbonate equivalent: Carbonates were determined by the modified A.O.A.C. (1955) procedure for determining carbonate carbon. CO_2 was evolved by treating the sample with H_2SO_4 and $FeSO_4$

and absorbed in ascarite or carosite and determined gravimetrically.

Exchangeable cations and exchange capacity: Exchangeable cations were extracted from the sample with normal ammonium acetate adjusted to pH 7.0 as outlined in A.O.A.C. (1955). Exchangeable potassium and sodium were determined with the model D.U. Beckman Flame Spectrophotometer, whereas calcium and magnesium were determined by standardized E.D.T.A. titration.

Exchangeable acidity was determined by 0.5 N barium acetate adjusted to pH 7.0 and titrated with standardized NaOH as suggested by Brown (1943).

The cation exchange capacity was determined by extraction of adsorbed ammonia with normal sodium chloride and distillation of the extract was carried out according to the magnesium oxide method for ammoniacal nitrogen outlined in A.O.A.C. (1955). Cation exchange capacity of the clay sample was determined similarly but modified to exclude the sodium chloride washing and to include the distillation of the total sample rather than extract.

Iron oxide content of the mineral horizons was determined by two methods. Jackson's (1956) method consists of consecutive washing with hydrosulfite and sodium citrate and removes both crystalline and amorphous material. The oxalate extraction outlined by McKeague and Day (1966) removes only the amorphous material. Iron in the extracts was determined colorimetrically using ortho-phenanthroline.

Aluminum oxide was extracted with oxalate McKeague and Day (1966) and determined colorimetrically.

Total ash of the organic horizons was determined by heating

samples to 600° C. for an hour and gravimetrically determining the weight loss. The ash was dissolved in 3 N HCl as suggested in A.O.A.C. (1955) and made to volume. The solutions were analysed for calcium, magnesium, potassium and iron using a Perkin Elmer Model 303 atomic adsorption unit.

Organic Analysis

Hydrolysis: The organic material of the leaf mat was hydrolyzed using a method outlined by Ivarson and Sowden (1962). One gram of sample was treated with 4.2 ml. of 72 per cent H_2SO_4 for two hours, diluted to 100 ml. and refluxed for 16 hours. For duplication, the procedure must be very carefully standardized.

Sugar analysis: Hexose: This was carried out using anthrone reagent on the filtered hydrolyzate as outlined by Brink et al. (1960). A 5 ml. portion of the hydrolyzate was treated with 10 ml. of 95 per cent sulfuric acid and anthrone mixture. The concentration was thus determined colorimetrically.

Pentose: The pentose determination was carried out on the hydrolyzate using a method outlined by Tracey (1950). Aniline-acetate was used to develop the color.

Uronic acids: The uronic acid sugars were determined using a method outlined by Lynch et al (1957) and modified by Bitter and Ewins (1961). Carbazole was used to develop the color.

Mineralogical Analysis

Clay separation was carried out using a method outlined by Pawluk.

The method consists of dispersion of the clays by adjusting the suspension to pH 8.0 with sodium hydroxide. The suspension was allowed to equilibrate overnight and the pH was readjusted to pH 8.0. The separation was accomplished by repeated decantations of the upper 8 cm. of suspension after standing for 6 hours and 8 minutes. The decanted clays were flocculated with magnesium using magnesium chloride followed by washing with distilled water to remove the chlorides.

X-ray analysis: Identification of the clay minerals present was made using a Phillips X-ray diffractometer with high angle goniometer. The radiation was Cu K α using a nickel filter. Suspensions of the clay were mounted on glass slides according to the method of Kittrick (1961) which involves placing a few drops of the suspension on a slide and allowing the clay to dry overnight. Ethylene glycol treatment of the air-dried mounted suspension was carried out by placing the prepared slides in a saturated atmosphere of ethylene glycol. A duplicate slide of the sample was heat treated at 500° C. for 2 hours and stored in a dessicator.

Differential thermal analysis of the clay samples was determined using the Aminco Thermal Analyzer. The magnesium saturated clays were ground to pass a 60 mesh sieve and packed in the furnace. Temperature rise was set at 16° C. per minute with a shutoff maximum of 1020° C. The thermal couples used were Cr/Al.

Surface area was determined using the method outlined by Heilman et al. (1965). Samples were ground to pass a 60 mesh sieve prior to treatment with ethylene glycol monoethyl ether in the vacuum dessicator. A standard sample was determined with each set.

Elemental analysis of the clays was carried out to determine the potassium content. Samples were treated with 1:1 HCl and H_2O and heated until the solution turned a yellowish color at which time the supernatent was decanted and centrifuged. Any residue was returned to the Teflon beakers and the samples were evaporated to near dryness. Samples were then treated with two 10 ml. volumes of HCl and HF with intermittent evaporation to near dryness. After the second HCl and HF treatment, the samples were heated to dryness, treated with 5 ml. of HCl and again heated to dryness. The residue was taken up in 5 per cent HCl and made to volume before potassium was determined with the Perkin Elmer Model 303 atomic absorption unit.

Microbiological Analysis

Plate count was used as a basic means of comparing the micro-biological populations at each vegetative site. Samples were taken from each site for the instruction and preparation of media. Distilled water was leached through these samples (1 litre per 1000 gms.) and made to 1000 ml. ; pH was determined and total solid content of this extract was determined gravimetrically. To adjust total solid content of extract from the different vegetative types to the same value, all were diluted to equal the extract of lowest solid content. No attempt was made to adjust the pH of the different extracts to the same values. To this solution was then added the gelatin required for the preparation of the various required media; solid, semi-solid and liquid. Such a media allows laboratory growth in material very similar to that found in the field. Samples for counting were taken in duplicate at each vegetative site. A weighted

quantity was placed in a known volume of sterile water which was then diluted in series. From each dilution 0.1 ml. of solution was spread on 5 previously prepared plates. Two to three days of incubation were allowed before plates were counted and a plate containing from 50 to 75 organisms was selected. From this plate all organisms were separated and placed in a tube of semi-solid agar where they were stored under refrigeration until required.

Microscopic study: The stored organisms were placed in liquid medium and incubated for 48 hours at which time slides were prepared using nigrosin stain. Microscopic examination allowed for the place-ment in various morphological groupings.

IV. RESULTS AND DISCUSSION

Physical, chemical, mineralogical, microbiological and bio-chemical analyses were conducted on soil samples collected from different vegetative sites in an effort to characterize the soil pedons and possibly find some explanation for the obvious morphological variations (Tables VI to XI and Figures 2. to 21.).

Mechanical composition was determined in order to evaluate the degree of uniformity of the soils sampled and to provide evidence as to movement and accumulation of clay, especially the fine clay, in the soil solum.

Chemical analyses were conducted in order to characterize the soil under study and assist in determining potential differences in the mineral decomposition effect of the leaf litter. The mineral composition of the leaf and leaf litters should, to some extent, be reflected in the exchangeable cation distribution of the underlying soils. The accumulation of materials, such as iron oxide in various horizons, also provides evidence of illuviation and/or weathering "in situ."

Mineralogical analyses and clay mineral identification reveals some of the genetic characteristics of the soil profile. Lithological composition of the soil sola reflects the nature of the parent materials and pedogenic alterations.

Biochemical studies are employed to provide evidence as to differences in leaf and leaf litter composition. Microbiological population studies in conjunction with the biochemical studies serves as an indicator of potential differences in the composition of the effluent that leaches through the soil profile. Differences may be expected and may

explain, at least in part, variations in morphology within the soil pedons associated with the different vegetative types.

Physical Analyses

Mechanical Analyses provides the percentage distribution of particle size in a soil sample (Baver, 1959). The size separations are those suggested by the Canadian Soil Classification Committee and are reported in Table VI.

A gleyed carbonated Dark Gray profile was found to occur at Site 1. Clay mineral distribution suggests a lack of clay movement; however, considerable variation in sand and silt content was evident. Such variability may be expected in glacial tills.

The profile at Site 2 has an increase in clay content downward in the profile with the maximum occurring in the Bt horizon. Profiles at Sites 3 and 4 are typical of the Podzolic order. Although the profile at Site 4 is of a finer texture, there is an increase in clay and fine clay in the Bt horizon. There is very little clay in the Ae of the profiles at Sites 3, and 4, indicating the high degree of eluviation.

The profile under the grassland vegetation at Site 5 appears in the field to be only very weakly eluviated. Mechanical analysis of this profile indicates a significant increase in clay content of the Btj horizon. This increase may be the result of the translocation of the clay minerals or it may be a stratification caused by the slumping of the river bank which has been blended since into a soil profile through various pedogenic processes. Another possibility is the removal of forest with subsequent grass invasion which would rehumify the Ae developed under the forest vegetation (Lavkulich et al., 1964).

TABLE VI (a)

CHEMICAL AND PHYSICAL

Horizon	Hygro. M.	pH	N %	Total Carbon %	C/N	CaCO$_3$ %
Site 1	**Gleyed Carbonated Dark Gray**					
Ah	2.29	7.7	0.19	2.24	11.6	0.40
Bkgj	1.68	7.7	0.05	0.66	12.4	2.06
BCkgj	1.44	7.7	N.D.***	0.79	N.D.	3.54
Ckgj1	1.47	7.8	N.D.	1.09	N.D.	4.04
Ckgj2	1.73	7.8	N.D.	1.66	N.D.	6.13
Site 2	**Bisequa Gray Wooded**					
Ae1	1.32	4.8	0.17	1.47	8.5	N.D.
Bfj	1.34	5.8	0.05	0.28	6.1	N.D.
Ae2	2.02	5.6	0.03	0.31	7.2	N.D.
Bt	2.19	5.5	N.D.	0.07	N.D.	N.D.
IIC	0.84	5.6	N.D.	N.D.	N.D.	N.D.
Site 3	**Orthic Gray Wooded**					
Ae	0.93	5.4	0.04	0.37	8.8	N.D.
AB	1.82	5.1	0.05	0.36	6.4	N.D.
Bt1	2.17	5.6	0.06	0.44	7.9	N.D.
Bt2	2.90	4.9	0.03	0.42	13.2	N.D.
BC	2.87	5.3	0.03	0.44	16.1	N.D.
C	2.96	7.1	N.D.	N.D.	N.D.	4.70

* Extracted with sodium dithionite
** Extracted with ammonium oxalate
*** Not determined

ANALYSES OF SOIL PROFILES

Extractible Oxides				Mechanical Analyses		Fine
Fe* %	Fe** %	Al** %	Sand %	Silt %	Clay %	Clay %
N. D.	N. D.	N. D.	31	48	21	6
1. 43	0. 10	0. 05	31	46	23	8
1. 36	0. 08	0. 03	43	33	24	13
1. 76	0. 08	0. 02	28	47	25	10
1. 90	0. 15	0. 03	41	28	31	10
0. 88	0. 07	0. 03	47	44	9	4
1. 16	0. 16	0. 06	39	48	13	2
1. 32	0. 12	0. 05	25	54	21	8
1. 64	0. 11	0. 04	45	31	24	14
0. 80	0. 10	0. 05	82	5	13	6
1. 03	0. 12	0. 05	50	40	10	0
1. 50	0. 13	0. 05	43	32	26	14
1. 74	0. 12	0. 05	40	29	31	21
2. 10	0. 12	0. 06	35	28	37	19
2. 10	0. 11	0. 05	34	30	36	19
2. 10	0. 10	0. 05	20	41	39	10

TABLE VI (b)

CHEMICAL AND PHYSICAL

Horizon	Hygro. M.	pH	N %	Total Carbon %	C/N	CaCO$_3$ %
Site 4	Solodic Gray Wooded					
Ae	0.94	5.4	0.09	0.96	11.0	N.D.***
AB	1.67	5.4	0.07	0.83	11.2	N.D.
Btnj1	3.26	4.8	0.09	0.84	9.8	N.D.
Btnj2	4.28	5.2	0.08	1.21	15.9	N.D.
BC	5.13	6.6	0.06	1.06	16.9	N.D.
C	4.72	7.2	N.D.	N.D.	N.D.	1.46
Site 5	Dark Gray					
Ah	6.97	5.6	0.72	10.9	15.2	N.D.
AB	4.83	5.0	0.17	2.51	14.4	N.D.
Bt	3.49	5.7	0.12	1.43	12.0	N.D.
BC	3.10	6.6	N.D.	1.24	N.D.	N.D.
IIC	2.32	7.9	N.D.	1.34	N.D.	1.33

* Extracted with sodium dithionite
** Extracted with ammonium oxalate
*** Not Determined

ANALYSES OF SOIL PROFILES

Extractible Oxides				Mechanical Analyses		
Fe* %	Fe** %	Al** %	Sand %	Silt %	Clay %	Fine Clay %
1.07	0.05	0.03	26	52	22	12
0.97	0.10	0.04	23	49	28	6
1.10	0.13	0.07	10	22	68	34
1.00	0.15	0.08	3	11	86	47
1.42	0.09	0.07	2	12	86	43
1.36	0.10	0.04	3	23	74	35
N.D.	N.D.	N.D.	11	35	54	24
1.28	0.05	0.07	11	40	49	15
1.48	0.06	0.06	11	24	65	34
1.70	0.05	0.05	18	33	49	23
1.72	0.04	0.05	24	41	35	15

TABLE VII (a)

CATION EXCHANGE ANALYSES

Horizon	% of Total Exchangeable Cations					Total C.E.C. me./100 g.	
	H^+*	Na^+	K^+	Ca^{++}	Mg^{++}	Sum of Ex. Cat.	Deter-mined
Site 1	Gleyed Carbonated Dark Gray						
Ah	0	1.5	1.5	77.6	19.4	30.8	24.2
Bkgj	0	1.1	2.2	74.8	21.9	18.7	11.8
Site 2	Bisequa Gray Wooded						
Ae1	48.2	1.5	3.0	30.8	16.5	12.1	9.5
Bfj	43.8	2.7	5.5	36.5	11.5	9.6	8.2
Ae2	14.6	3.5	5.2	55.1	21.6	11.6	9.8
Bt	14.2	2.1	3.5	62.5	17.7	14.1	11.9
IIC	15.5	10.4	3.9	61.1	9.1	7.7	6.7
Site 3	Orthic Gray Wooded						
Ae	34.4	3.1	3.1	57.8	1.6	6.4	6.3
AB	20.5	2.8	2.8	66.0	7.8	14.1	12.2
Bt1	16.3	1.7	2.8	62.4	16.8	17.8	15.1
Bt2	16.4	1.7	2.6	64.6	14.6	23.2	19.6
BC	14.1	1.2	2.0	67.0	15.7	24.2	17.3

* Exchange Acidity

TABLE VII (b)

CATION EXCHANGE ANALYSES

Horizon	H^+*	Na^+	K^+	Ca^{++}	Mg^{++}	Total C.E.C. me. / 100 g. Sum of Ex. Cat.	Determined
Site 4	**Solodic Gray Wooded**						
Ae	24.6	14.3	6.3	40.5	14.3	12.6	9.4
AB	26.9	4.2	6.7	39.5	22.7	11.9	10.5
Btnj1	16.5	4.3	5.1	40.8	33.3	25.5	27.6
Btnj2	9.7	5.5	4.0	39.8	41.0	34.7	33.2
Site 5	**Dark Gray**						
Ah	12.5	1.8	4.1	65.5	16.1	43.0	37.3
AB	17.2	3.7	3.7	49.2	26.2	29.5	28.4
Btj	6.1	1.8	4.1	55.9	32.1	29.5	27.3
BC	2.5	2.5	5.4	58.7	30.9	16.5	19.1

Note: The header for the cation columns reads "% of Total Exchangeable Cations"

*Exchange Acidity

TABLE VIII (a)

CHEMICAL AND PHYSICAL

Horizon	pH Fall	Spring	Hygro. M. Fall	Spring	% Ash Fall	Spring
Site 1	Balsam Vegetation					
L	7.1	6.6	10.2	11.6	16.5	18.6
F	6.6	7.2	11.0	18.1	21.5	24.8
H	6.9	7.0	10.9	14.0	42.2	40.2
L	7.4	6.7	10.1	11.6	16.9	14.4
F	7.1	6.9	10.8	14.4	23.9	26.8
H	6.9	7.0	11.0	13.3	43.9	43.2
L	7.1	6.3	9.9	10.7	15.4	15.7
F	7.0	6.8	11.2	14.6	24.7	29.9
H	6.9	7.3	12.8	9.6	39.1	67.4
Site 2	Pine Vegetation					
L	5.1	5.2	7.8	8.3	9.5	5.8
F	4.8	4.8	6.8	8.4	21.0	14.1
L	5.1	5.5	7.1	8.4	10.9	9.7
F	4.9	5.3	7.3	9.7	23.6	22.3
L	5.1	5.6	4.9	8.4	9.3	12.6
F	5.6	5.4	7.1	8.7	28.1	23.0

ANALYSES OF ORGANIC MATERIALS

Total C.E.C. me./100 g.		% Carbon		% Nitrogen		C/N	
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
106	98	43.5	41.8	1.52	1.69	28.6	24.7
127	162	38.6	38.4	1.73	1.46	22.4	26.3
149	134	30.4	32.3	1.52	1.38	19.9	23.4
108	90	41.9	44.4	1.76	1.64	23.8	27.2
125	121	39.2	41.2	1.76	1.55	22.2	26.5
138	127	30.7	31.6	1.48	1.40	20.8	22.7
102	90	43.3	43.4	1.74	1.63	24.9	26.7
127	116	40.4	34.7	1.73	1.69	23.3	20.5
152	87	31.9	30.9	1.59	1.56	20.0	19.9
57	49	46.2	46.9	0.89	0.68	51.9	69.1
68	71	40.9	43.6	1.12	0.99	36.6	44.0
58	54	46.5	45.8	0.93	0.67	49.9	68.7
83	71	40.6	39.6	1.21	1.24	33.5	31.8
69	52	47.9	44.3	0.83	1.01	58.0	43.6
83	65	35.1	38.7	1.13	1.22	30.9	31.6

TABLE VIII (b)

CHEMICAL AND PHYSICAL

Horizon	pH Fall	pH Spring	Hygro. M. Fall	Hygro. M. Spring	% Ash Fall	% Ash Spring
Site 3	Aspen Vegetation					
L	6.6	6.2	9.6	11.3	16.6	16.6
F	6.0	6.0	10.4	12.9	32.1	24.1
L	6.6	6.2	9.3	10.4	16.0	15.4
F	6.2	5.8	12.0	15.7	21.9	23.8
L	6.5	6.3	7.3	10.6	17.8	15.5
F	6.6	5.6	9.5	10.2	28.5	31.7
Site 4	Spruce Vegetation					
L	6.6	6.0	8.9	10.2	22.5	18.9
F	5.8	5.6	8.6	9.3	37.7	39.1
L	6.5	6.2	8.4	9.7	26.8	15.5
F	5.8	5.7	11.2	12.0	22.6	17.5
L	6.4	6.1	8.2	10.3	19.6	21.7
F	6.1	5.8	10.3	10.5	23.6	34.4

ANALYSES OF ORGANIC MATERIALS

Total C.E.C. me./100 g.		% Carbon		% Nitrogen		C/N	
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
89	89	43.6	41.2	1.75	1.75	25.0	23.5
89	114	43.5	38.9	2.13	1.95	20.4	19.9
94	87	44.7	42.1	1.87	1.70	23.9	24.8
104	98	41.7	37.8	2.29	1.75	18.2	21.7
97	92	41.9	43.1	2.05	1.79	20.5	24.0
108	87	40.0	35.2	2.13	1.74	18.8	20.0
80	98	40.5	43.9	1.18	1.47	34.4	29.9
91	91	37.3	32.8	1.63	1.28	22.9	25.6
70	84	39.1	42.1	1.23	1.29	31.6	32.5
110	102	39.8	39.8	1.63	1.42	24.4	28.1
65	77	44.4	39.7	1.10	1.09	40.0	36.2
103	84	42.4	32.9	1.67	1.26	25.3	26.2

TABLE VIII (c)

CHEMICAL AND PHYSICAL

Horizon	pH Fall	Spring	Hygro. M. Fall	Spring	% Ash Fall	Spring
Site 5 Grass Vegetation			.			
O. M.	6.9	6.6	6.4	7.3	53.8	48.6
Sod	6.7	6.6	5.9	8.1	64.6	54.8
Ah	6.2	6.3	3.8	4.2	85.6	85.7
O. M.	6.9	6.9	7.9	8.3	50.0	47.4
Sod	7.0	6.7	7.1	5.8	65.6	70.8
Ah	6.0	6.4	4.1	4.9	75.6	82.1
O. M.	7.2	6.9	8.6	9.5	44.2	42.2
Sod	5.8	6.7	6.5	7.3	64.5	60.5
Ah	6.8	6.5	3.1	4.9	86.9	74.4
Leaves						
Balsam	N. D. *	N. D.	10.6	N. D.	12.6	N. D.
Pine	N. D.	N. D.	9.0	N. D.	3.2	N. D.
Aspen	N. D.	N. D.	8.3	N. D.	11.9	N. D.
Spruce	N. D.	N. D.	9.3	N. D.	4.9	N. D.
Grass	N. D.	N. D.	10.8	N. D.	9.0	N. D.

*Not Determined

ANALYSES OF ORGANIC MATERIALS

Total C.E.C. Me./100 g.		% Carbon		% Nitrogen		C/N	
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
75	65	24.0	25.7	1.63	1.51	14.8	17.0
67	66	14.6	20.6	1.31	1.61	11.2	12.7
45	33	7.5	5.8	0.71	0.45	10.6	12.7
95	76	24.7	24.6	1.79	1.70	13.8	14.5
71	55	16.0	13.3	1.33	1.06	12.1	12.5
53	39	7.8	7.1	0.75	0.63	10.5	11.2
104	89	26.0	27.2	2.01	2.01	12.9	13.5
68	67	16.1	17.0	1.42	1.51	11.4	11.3
39	44	4.7	10.3	0.53	0.90	8.9	11.4
57	N.D.	43.8	N.D.	1.71	N.D.	25.7	N.D.
31	N.D.	50.6	N.D.	0.93	N.D.	54.5	N.D.
52	N.D.	42.9	N.D.	1.57	N.D.	27.6	N.D.
52	N.D.	49.2	N.D.	0.90	N.D.	54.9	N.D.
21	N.D.	42.5	N.D.	1.33	N.D.	31.9	N.D.

Ash content of leaves and leaf litters: The ash content data is presented in Table VIII. The data indicates that the leaves from coniferous vegetation have a lower ash content than the leaves from grass or deciduous vegetation, a finding which is reported by Lutz (1948). In the vegetation investigated, pine leaves have the lowest ash content and balsam leaves the highest. A comparison of analyses from the litters show pine to have the lowest ash content and grass the highest. The high ash content of the grass litter can be explained by the intricate mixing of organic and mineral material associated with a chernozemic Ah horizon. The ash content of spruce, aspen, and balsam litters is very similar.

Hygroscopic moisture is to some extent a measure of the colloid content of a material (Baver, 1959). Values determined (Table VI) for the mineral horizons of the soils at Sites 2, 3 and 4 show an increase in hygroscopic moisture downward in the profile and is the result of an increase in clay content. The high values for the Ah horizons of the profiles at Sites 1 and 5 are the result of the organic matter present.

Comparison of the values determined for the leaf litters (Table VIII) show the pine and grass litters to have the lowest hygroscopic moisture content. The low content in the grass litter is the result of the high mineral content as compared to the other litters. The low value for pine results from the nature of the pine leaf. Aspen, spruce and balsam litters have similar hygroscopic moisture contents. Generally, an increase in hygroscopic moisture content from the L to the F horizons of the litter is apparent.

Chemical Analyses

Exchangeable cations and cation exchange capacity generally reflect the pedogenic processes which have been operative in profile development.

The cation exchange capacity is directly related to the clay and organic content (Table VII). At Sites 2, 3 and 4 the increase in cation exchange capacity in the Bt horizon is the result of an increase in clay content while the high cation exchange capacity of the Ah horizons at Sites 1 and 5 results from the high content of organic matter. In all cases, the summation value is greater than the determined value. This trend was also noted by Coen (1965).

Cation exchange capacity of the leaf litter (Table VIII) is an indication of degree of decomposition and is related to the quantity of hydroxyl, phenyl and carboxyl groupings present in this material. Comparison of the cation exchange capacity of the different leaves show pine and grass to have the lowest content. The cation exchange capacity for aspen, spruce and balsam were similar but higher than for pine and grass.

A similar trend is generally exhibited in the leaf litter, with the exception of balsam which has a much larger cation exchange capacity than the other litters. The order of increasing cation exchange capacity in the litter is pine $<$ grass $<$ spruce $<$ aspen $<$ balsam. The low cation exchange capacity of the grass litter results from the high mineral content of this material.

Henderson (1963) states that during decomposition alcoholic groups are oxidized to the acid form. Kyuma (1964) states that the

shorter chain materials show increased humification and cation exchange capacity. A similar trend is indicated by the cation exchange data here where an increase in cation exchange capacity occurs with increasing depth and thus decomposition at Sites 1, 2, 3 and 4. The fact that this trend is not indicated at Site 5 (grass litter) is explained by the high mineral content of this litter. No differences were noted between the cation exchange capacities of the samples collected in the fall and spring.

Calcium is generally the dominant exchangeable cation found in the profiles collected at the various sites. An exception is the Ae horizon at Site 2 (pine vegetation) where exchangeable acidity occupies the dominant position on the exchange complex. The percentage exchangeable calcium decreases with increasing depth in the profiles at Sites 1 and 5 (balsam and grass vegetation respectively). At Sites 3 and 4 (aspen and spruce vegetation respectively) the per cent exchangeable calcium remains nearly constant with increasing depth while at Site 2 there is an increase in per cent exchangeable calcium with depth in the profile. The upper portion of the profile (Ae and Bfj) at Site 2 and the profile found at Site 4 have a lower per cent exchangeable calcium than the profiles found at the other sites.

Magnesium is generally the second most common cation present with the exceptions to this occurring in the upper eluviated horizons of the profiles found at Sites 2, 3 and 4. There is an increase in the per cent exchangeable magnesium with increasing depth.

Sodium is generally present in very small amounts. The per cent of exchangeable sodium is greatest in the profile at Site 4 where it

occupies approximately 5 per cent of the exchange complex. The Ae
of this profile has 14 per cent exchangeable sodium. Values for
increased depth are very erratic.

Potassium content is also low but is generally slightly higher
than the sodium content.

Exchange acidity results from the presence of aluminum and/or
hydrogen ions adsorbed on the exchange complex and as a result
exchangeable acidity is pH dependent. No exchangeable acidity is
present in the profile at Site 1. At the other sites there is a gradual
decrease in per cent exchangeable acidity with increased depth in the
profile. Exchange acidity occupies the second highest portion of the
exchange complex in the Ael and Bfj horizons of Site 2, Ae and AB
horizon of Site 3, and the Ae and AB horizons of Site 4.

pH values: Results of pH values (Table VI) for the mineral
horizons of soils at the various sites indicate that the soil reaction at
Sites 2, 3, 4 and 5 is acidic in the sola. These results are similar in
magnitude to those often found in the solum of Gray Wooded soils
(Pawluk, 1961). The soil profile at Site 1 is alkaline in reaction.

The pH values for the leaf litters (Table VIII) show pine at Site
2 to be the most acidic in reaction. The F layer is generally more
acidic than the L layers and may result from increased decomposition
with a concomitant increase in carboxyl content (Henderson, 1963).
The raw organic mat has a higher pH than the underlying Ah for the
grassland soil.

The litter at Sites 1 and 5 (balsam and grass respectively) have
the highest pH values and are approximately neutral in reaction. The

decrease in pH between the organic mat and the Ah horizon in the
grassland soil is about 0.6 units as compared to the samples of balsam
litter collected in the fall where the drop from L to H horizon is about
0.4 units. For the balsam samples, the pH trend is reversed in the
spring where the L layer is the most acidic (pH 6.5) and the H layer
the least acidic (pH 7.1).

The litters at Sites 3 and 4 (aspen and spruce respectively) have
about the same pH values ranging from 5.6 to 6.6. At these sites the
samples collected in the spring tend to be slightly more acidic in
reaction than the samples collected in the fall. This is a reversal of
the trend found for the results from the pine litter where the pH values
are higher in the spring than the fall samples.

Calcium carbonate equivalent: The pH values of the soils
studied indicate that these profiles are alkaline in reaction in all
horizons at Site 1 and in the C horizons of Sites 3, 4, and 5. The cal-
cium carbonate values determined for Sites 3, 4, and 5 indicate the
presence of weakly calcareous parent material. The profile at Site 1
is weakly calcareous in the Bkgj, BCkgj and Ckgj1 and moderately
calcareous in the Ckgj2 horizon.

Carbon and nitrogen content: Total carbon is considered to be
a reliable estimate of organic carbon where calcium carbonate is absent
or present in very low amounts. At Site 1, the increase in total carbon
with depth below the Bkgj horizon results from the presence of larger
quantities of calcium carbonate. In general, there is a decrease in
the carbon content with increased depth in the sola with an exception
occurring in the Bt2 horizon of the profile at Site 4 (spruce vegetation)

where there is an increase in total carbon. Nitrogen content values follow a trend similar to that of carbon.

Carbon and nitrogen contents of the leaves and leaf litters (Table VIII) provide an index to potential rate and degree of decomposition. Comparison of data collected for the leaves show pine to have the highest carbon content with values for spruce only slightly lower. Balsam, grass and aspen have about the same carbon content, about 7 per cent less than that for pine. Spruce and pine have the lowest nitrogen content and consequently the highest C/N ratio (approximately 54). Aspen, balsam and grass have a very similar nitrogen content with a C/N ratio near 30. Comparison of data for leaf litters does not indicate the same trend. Here the pine has the highest carbon content and the highest C/N ratio. Aspen, balsam and spruce generally have similar carbon, nitrogen and C/N values which indicates that decomposition progresses at a similar rate. The low carbon and nitrogen values for the grass vegetation results from the high percentage of mineral material in these organic horizons. The low C/N ratio under the grass would indicate that this material is very well decomposed. The trend indicated for the L and F horizons of the leaf litters agrees with Gessel and Balci (Youngberg, 1963) who state that there is a decrease in carbon and an increase in nitrogen content with increased decomposition. A decrease in nitrogen content in the H layer of balsam litter is in agreement with Alexander's (1961) statement of a decrease in nitrogen content with increased decomposition.

Extractable iron oxides: Extractable hydrous oxides in soil profiles generally represent dissolution of inorganic soil constituents

and consequently reflects, to some extent, the degree of chemical weathering which has occurred.

The values reported (Table VI) for citrate-dithionite extractable iron are higher than values reported by Coen (1965) and Pawluk (1960) who used a hydrosulfite extraction. The difference may to some extent be due to the extractants used (Coffin, 1963). At Site 1 (balsam vegetation) the extractable iron content remains nearly constant downward in the soil profile. At the Sites 2, 3, 4 and 5 there is a gradual increase in the extractable iron content downward in the profile which is due to weathering and subsequent leaching.

The values for the oxalate extractable iron oxide are a measure of the amorphous iron in the profile (McKeague and Day, 1966). Data from the profiles at Sites 1, 3 and 5 (balsam, aspen and grass respectively indicate no movement and no horizon of accumulation in the profile. Site 2 (pine vegetation) exhibits a maximum content in the Bfj horizon while at Site 4 (spruce vegetation) this maximum content occurs in the Bt horizon of the profile. These values indicate that a more intensive mineral weathering associated with translocation of iron at Sites 2 and 4.

Extractable aluminum oxides were determined only on the oxalate extract. Data collected from the profiles indicate no translocation of amorphous aluminum oxides material.

Mineral analysis of leaf and leaf litter: The mineral content (Figures 2 to 6) (horizontal lines within each bar represent values for triplicate samples) of the various leaves and leaf litters gives an indication of differences in mineral composition of the effluent leaching
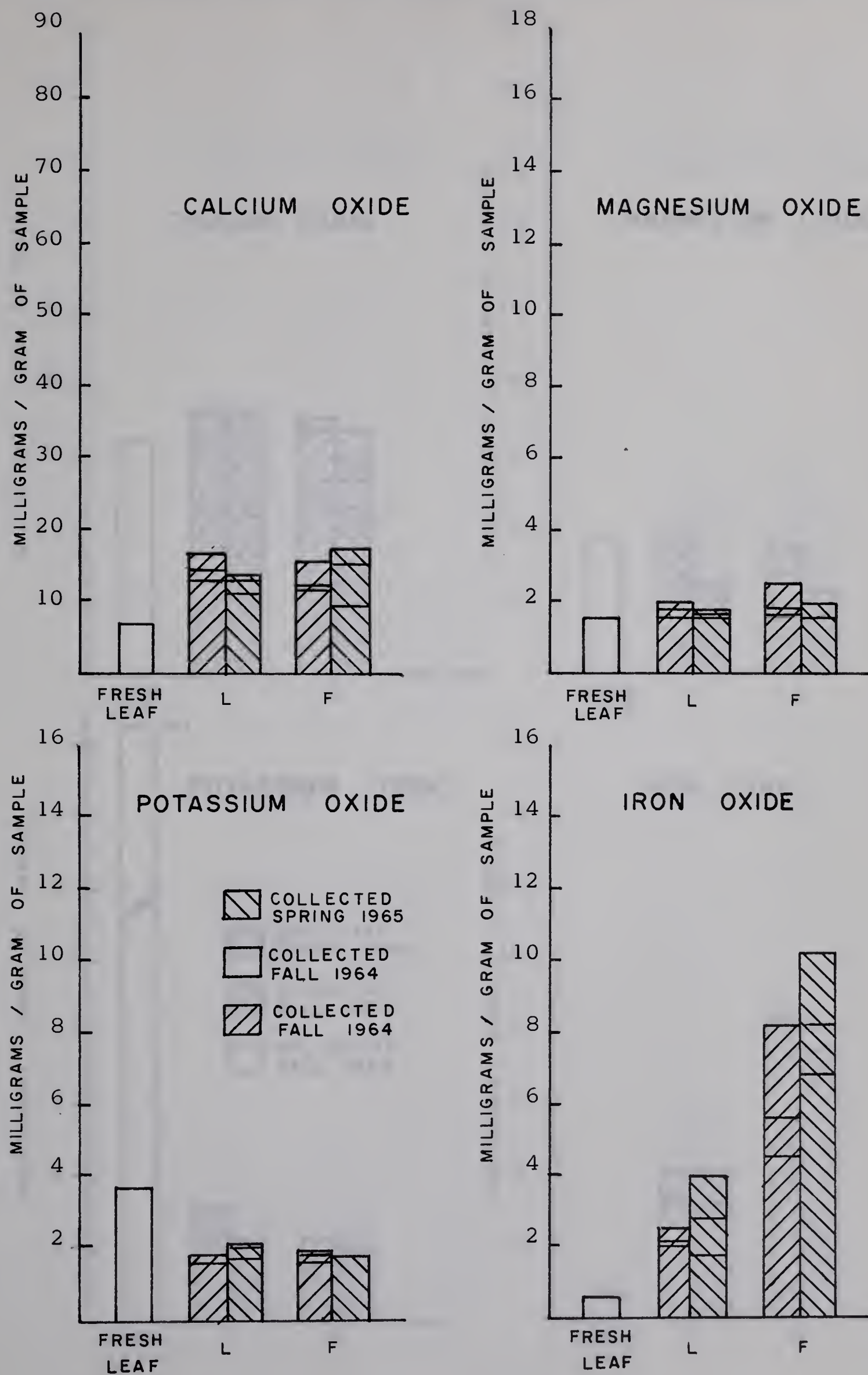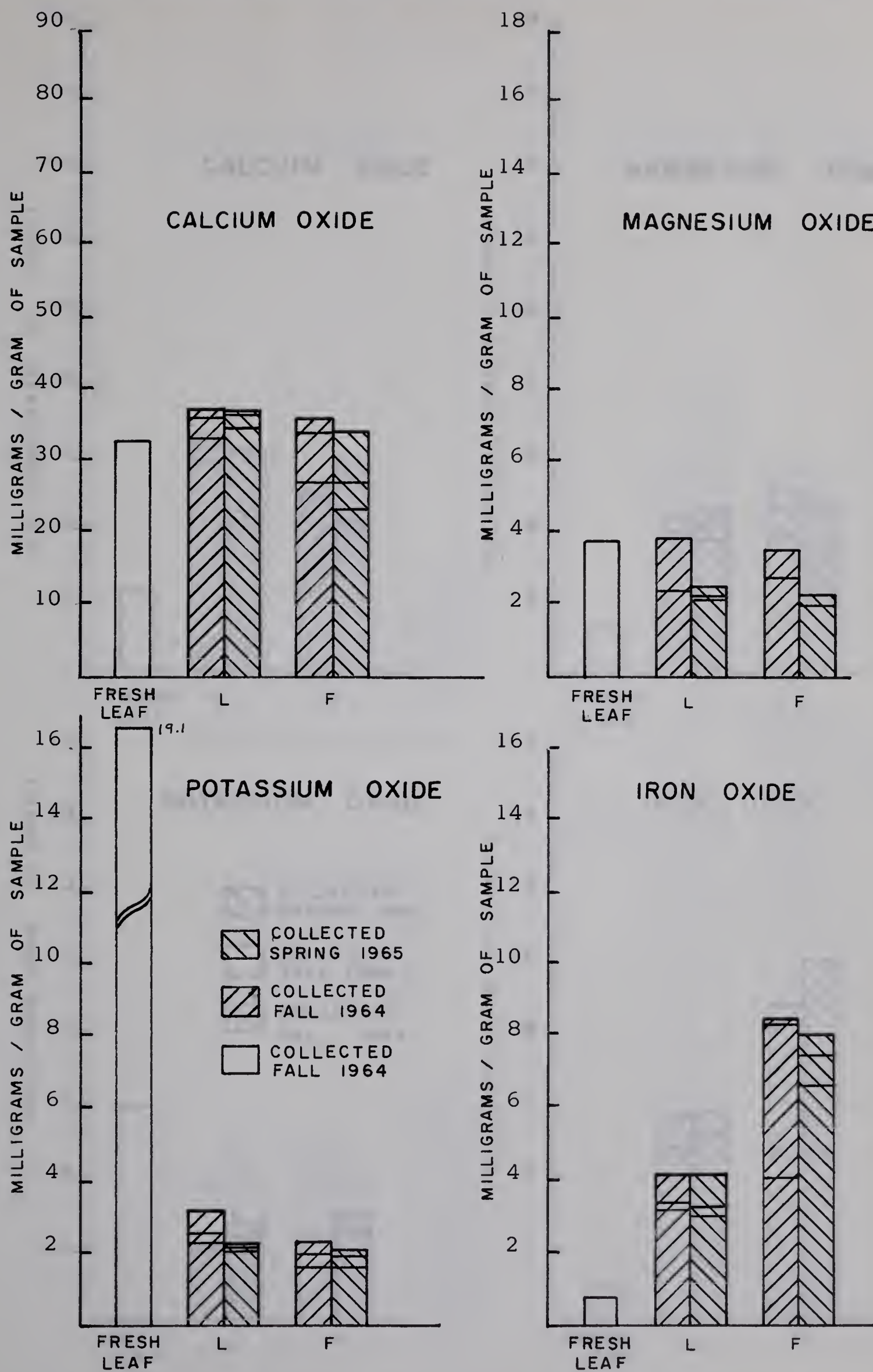
Site 1   Mineral Content of Organic Material   Figure 2
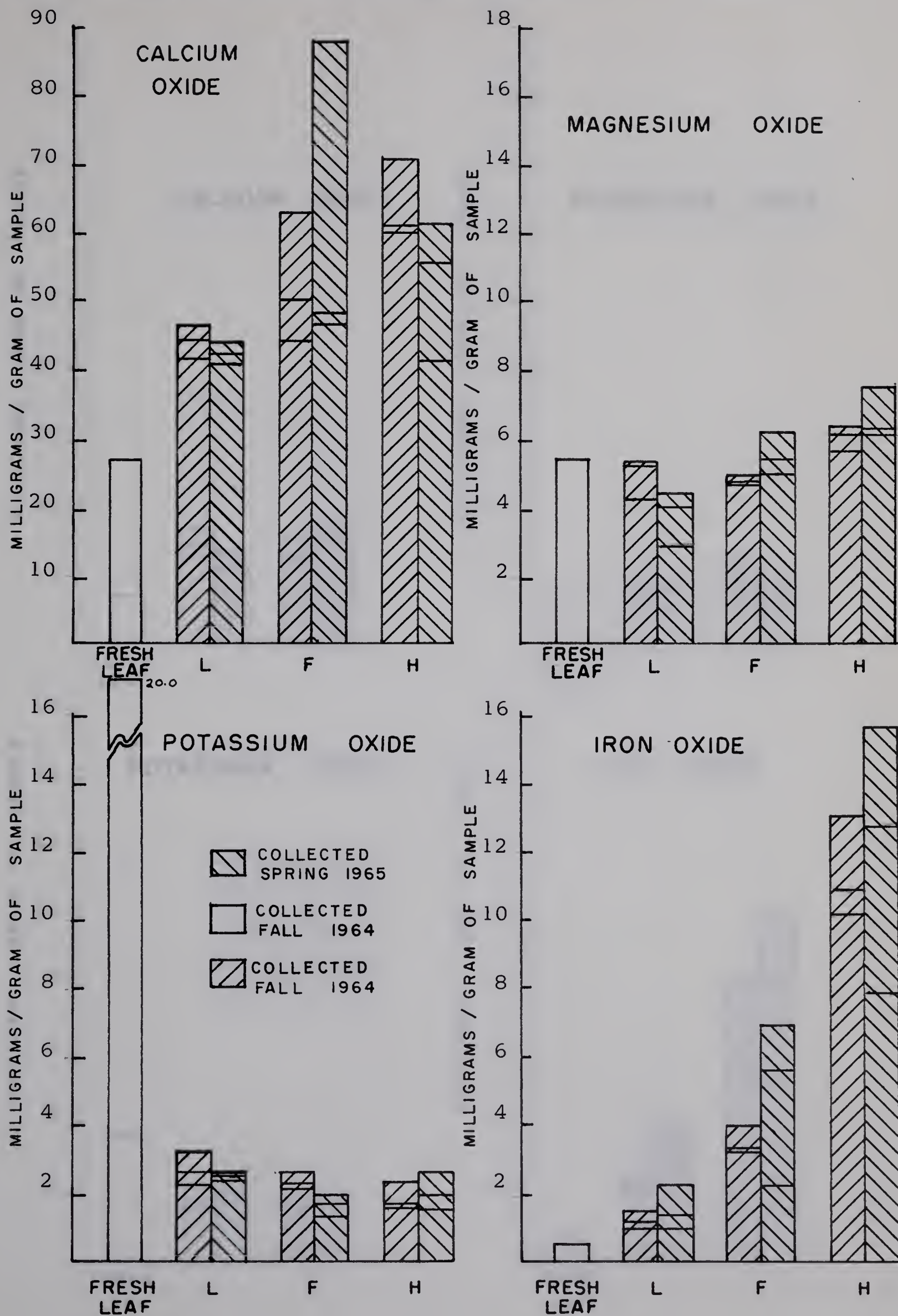
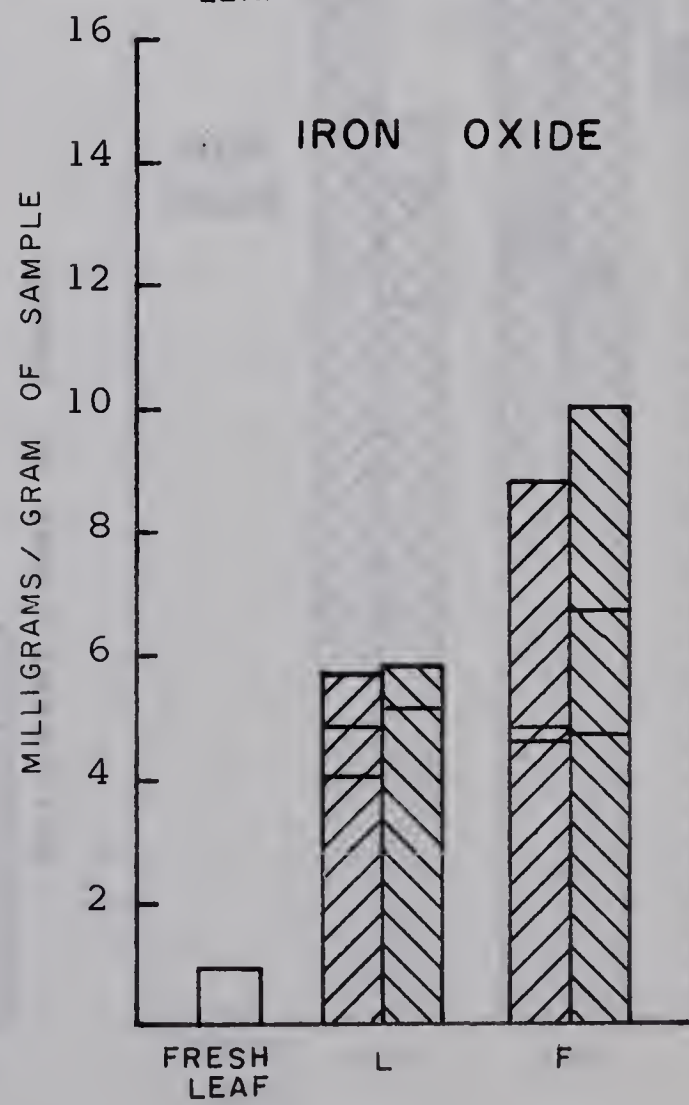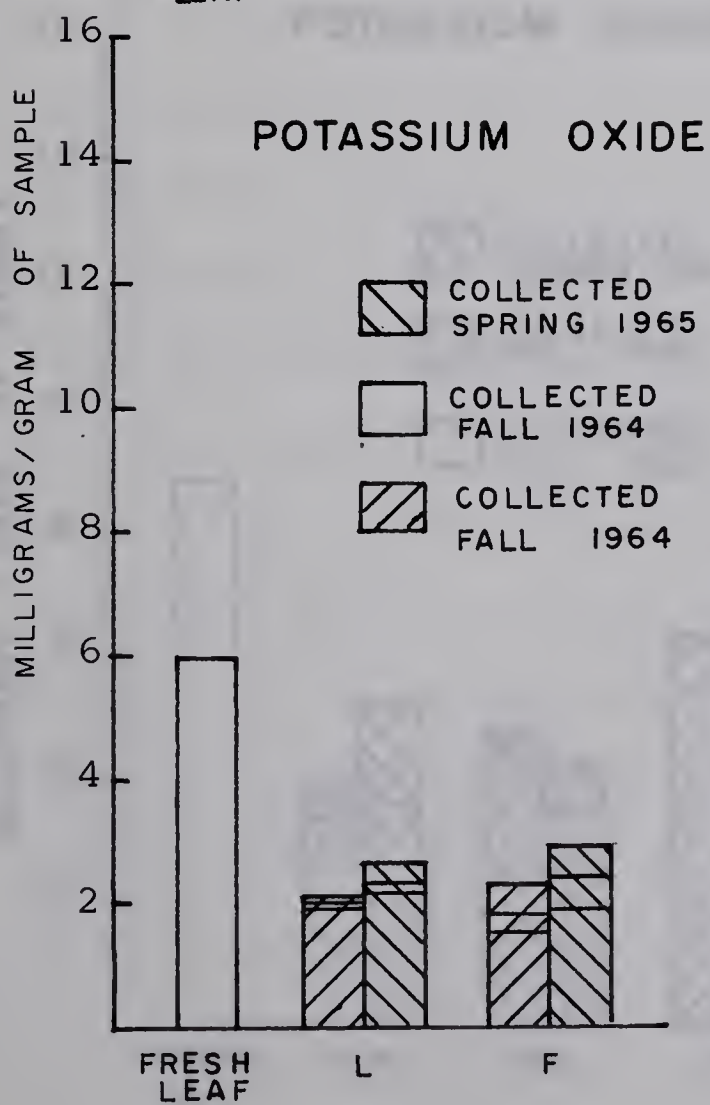Site 2   Mineral Content of Organic Material   Figure 3

Site 3   Mineral Content of Organic Material   Figure 4

MAGNESIUM OXIDE

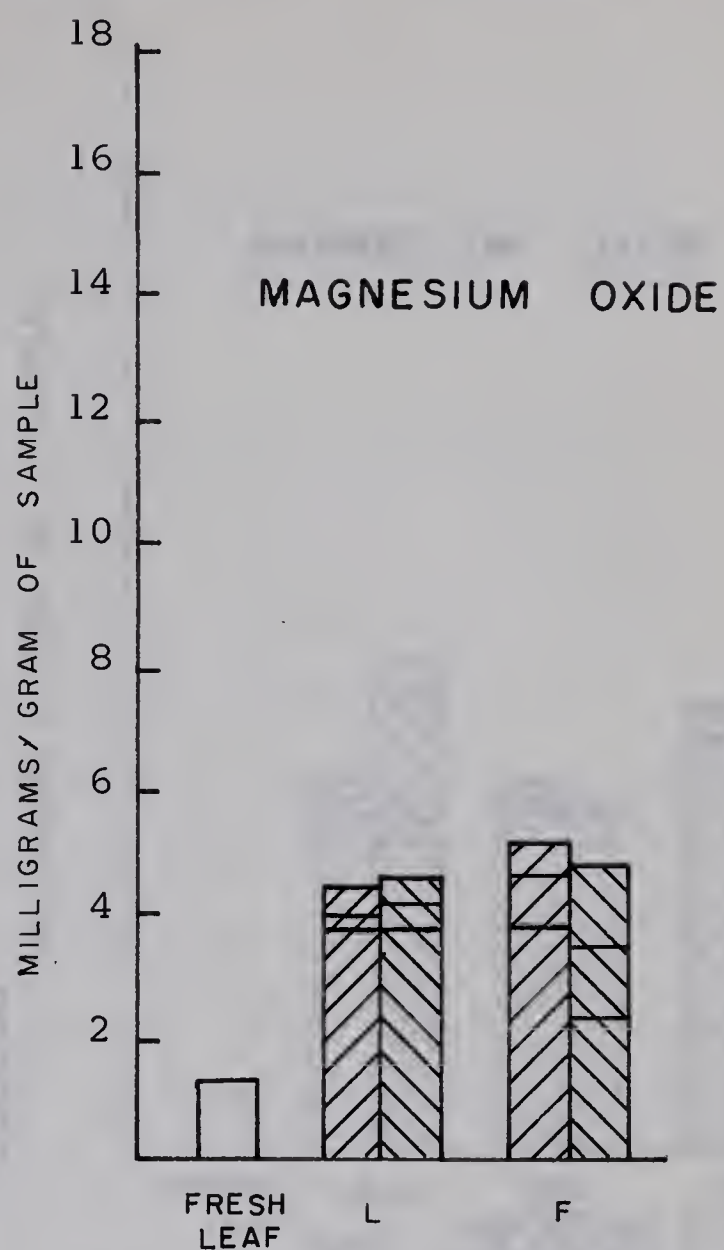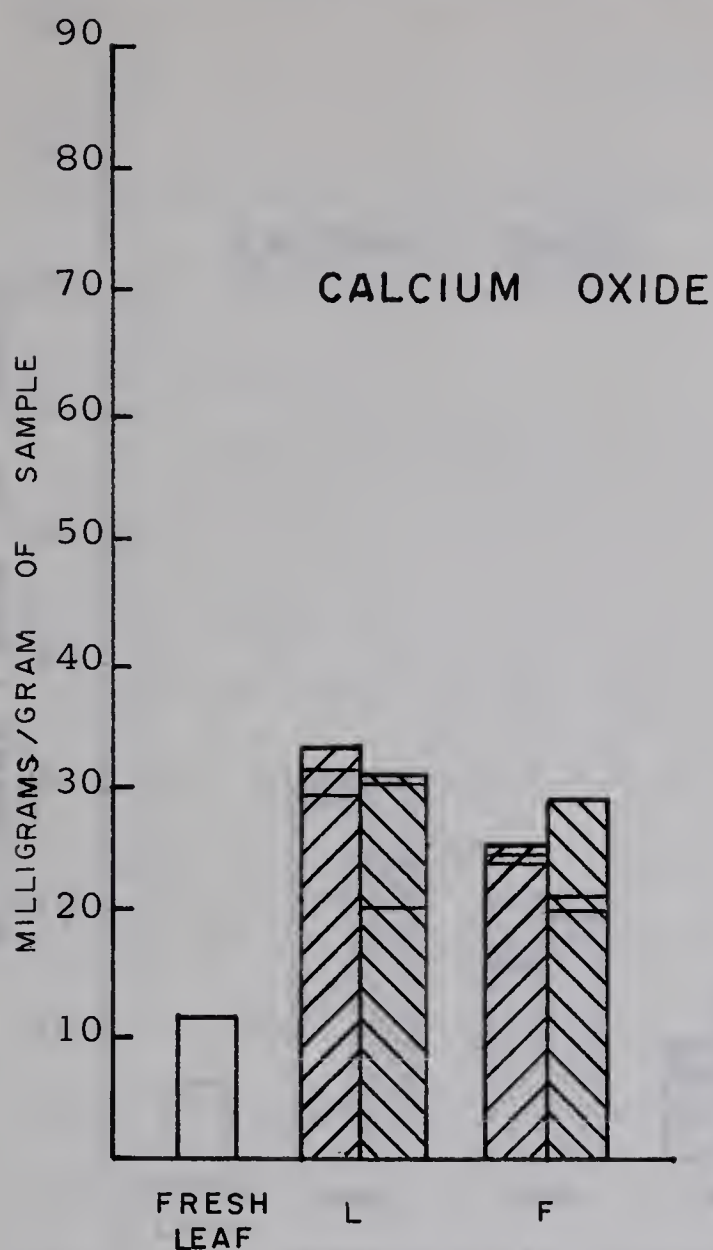CALCIUM OXIDE

IRON OXIDE

MANGANESE

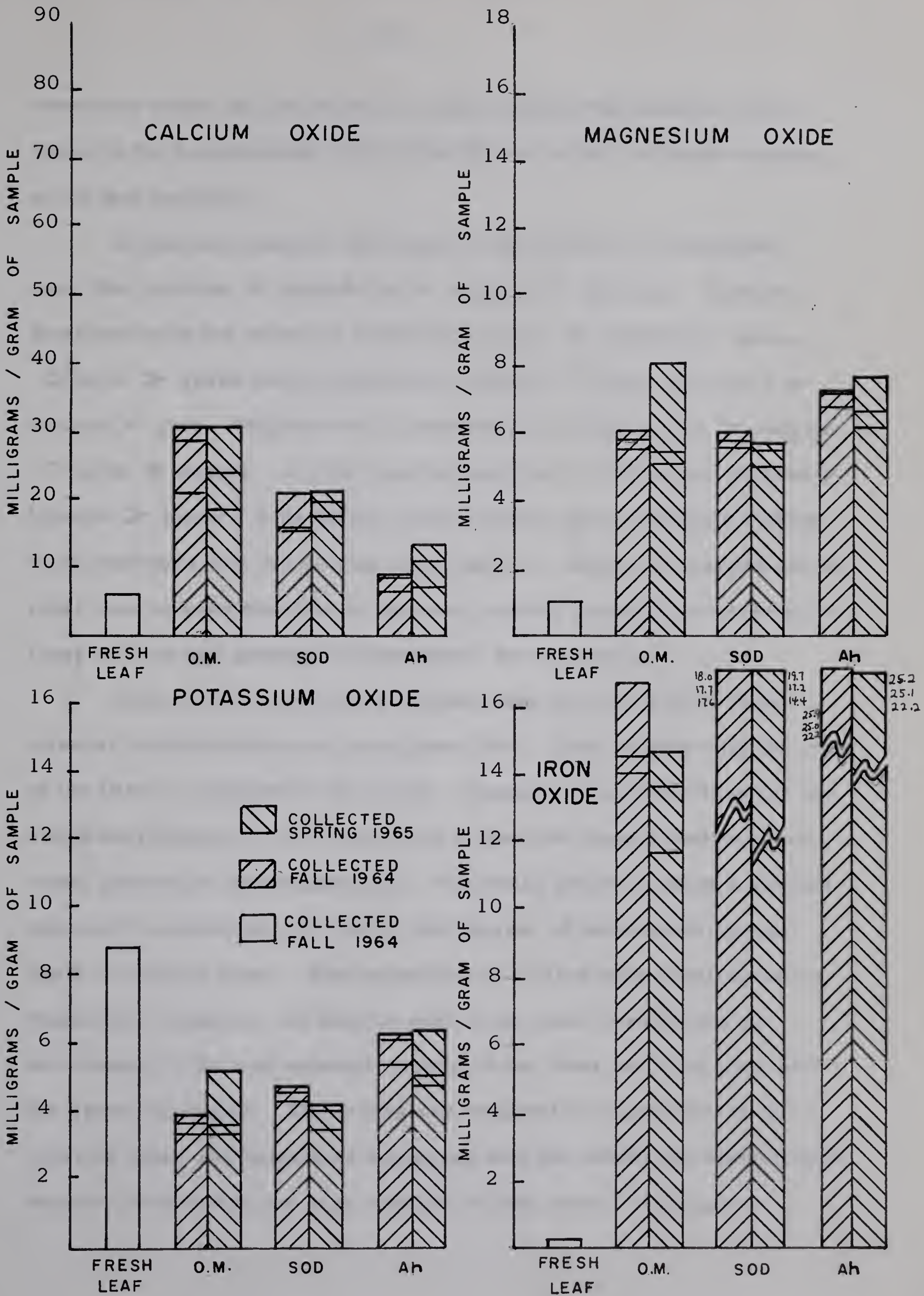Site 4   Mineral Content of Organic Material   Figure 5

Site 5   Mineral Content of Organic Material   Figure 6

downward in the soil solum and is subsequently expressed by differ-
ences in the exchangeable cation distribution on the exchange complex
of the soil profiles.

In the leaf material the mineral composition is distributed
such that calcium > potassium > magnesium > iron. Calcium
distribution in the leaves is found to be aspen > balsam > spruce
> pine > grass and for potassium balsam > aspen > grass >
spruce > pine. Magnesium is distributed such that aspen > balsam
> pine > spruce > grass and for iron spruce > aspen > pine >
balsam > grass. Lutz (1948) states that the plant materials richest
in all nutrients will decompose most rapidly. Balsam and aspen leaves
must thus be considered to be the most rapidly decomposed material of
those studied and grass the most slowly decomposed.

Lutz (1948) states that deciduous tree litter is higher in all
mineral materials than the evergreen litter. This is generally the case
in the litters compared in the study. Comparison of the litters for the
elements (Figures 2 - 6) shows pine to have the lowest content of cal-
cium, potassium and magnesium. All litters generally have a similar
iron oxide content that increases with degree of decomposition and
depth of organic layer. The accumulation of iron may result from its
immobility; however, at least in part it may also result from an
enrichment in the soil mineral content of the litter as is the case with
the grass vegetation. The low values obtained for potassium in the
litter of aspen and balsam as compared with the values for fresh leaves
may be attributed to the high mobility of this cation. Calcium is

immobilized by complexing with humates and subsequent dehydration (Joffe, 1949). This reaction explains the accumulation of calcium rather than potassium in the litter. The magnesium content of the litter is found to be grass > balsam > spruce > aspen > pine.

In summary, it may be concluded that grass litter has the greatest content of metallic cations while pine litter has the least. The balsam, spruce and aspen litters are very similar in content of most ions.

A comparison of metallic cation content between fresh leaves and litter suggests a considerable accumulation of calcium ions in the litter of grass, spruce and balsam. The high content in the balsam litter is the result of the presence of small amounts of free calcium carbonate, especially in the H horizon.

Biochemical analysis of leaves and leaf litters: The organic constituents of the litter have long been known to play a role in the movement of sesquioxides and clay minerals. An examination of data (Figures 7 - 11) (horizontal lines within each bar represents triplicate determinations) shows the polysaccharides to be higher in pine litter than from any of the other vegetative types. The samples collected in the fall are generally lower in hexose than those collected in the spring. Similar trends have been found by Ivarson and Gupta (1967). They state that frost increases the content of extractable sugar from leaf material 2 to 5 times. The increase in this study is not that intensive and may be explained by leaching which occurs during the spring runoff. This is to some extent supported by the fact that the greatest increase in values from fall to spring are found in the balsam litter
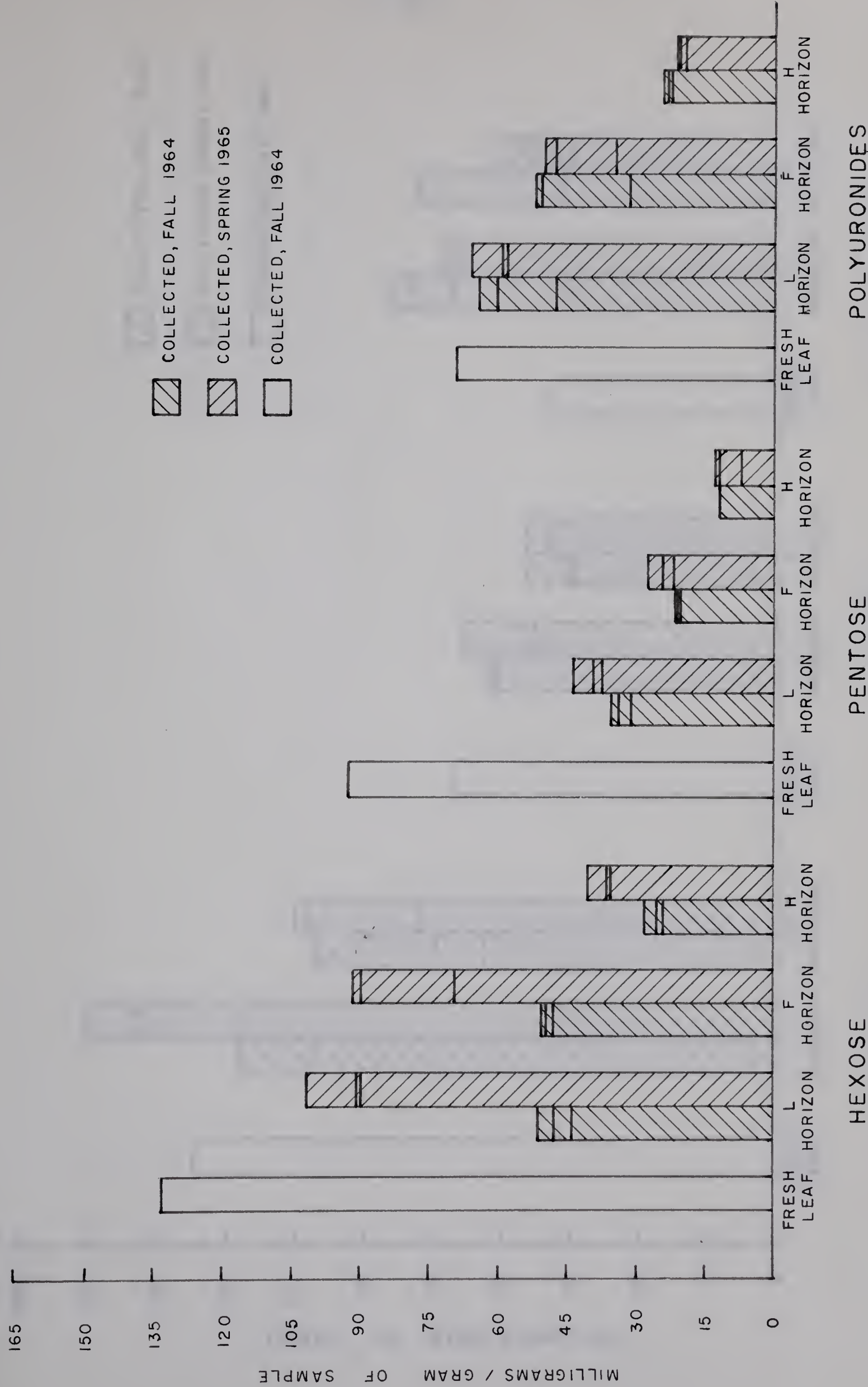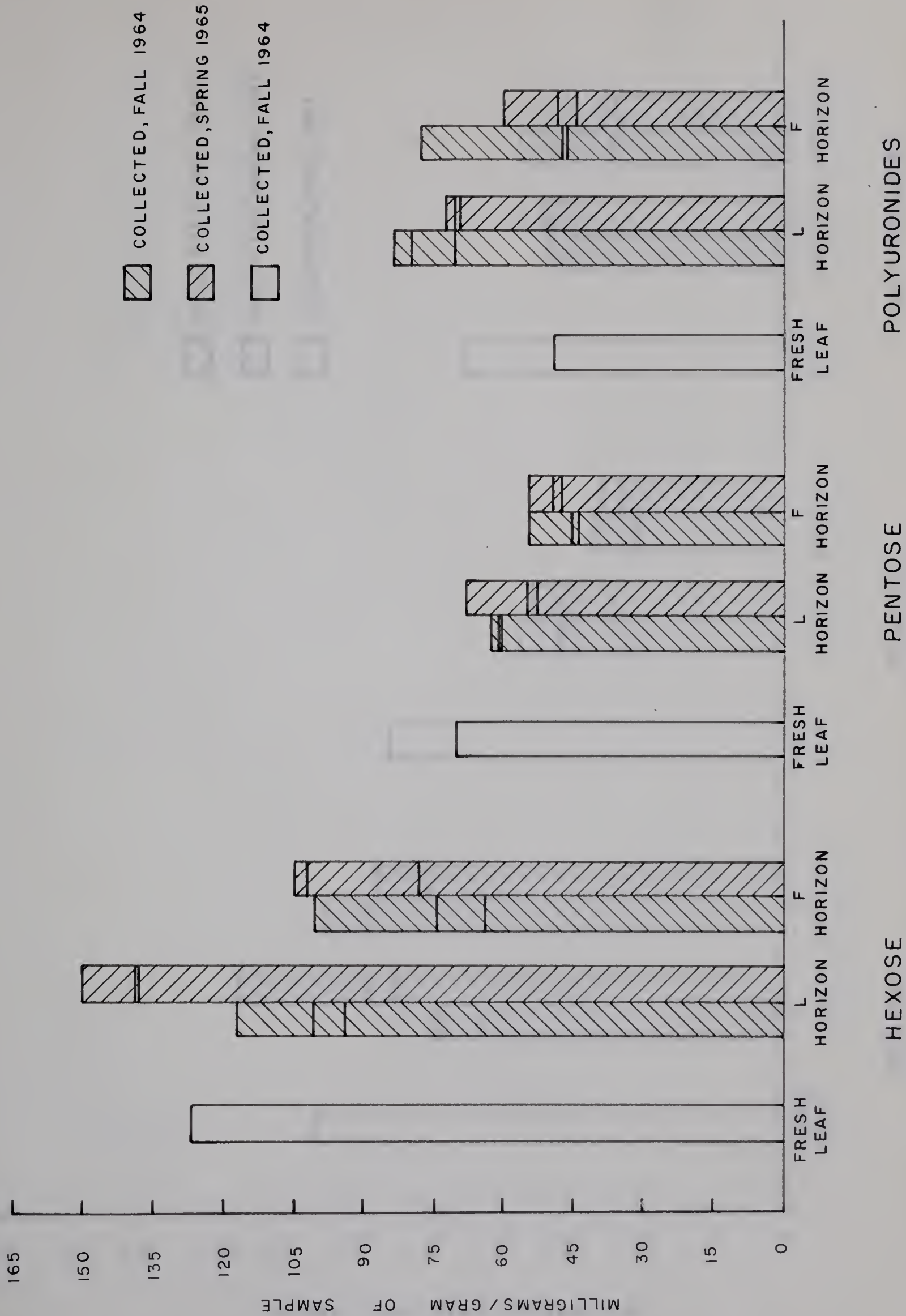
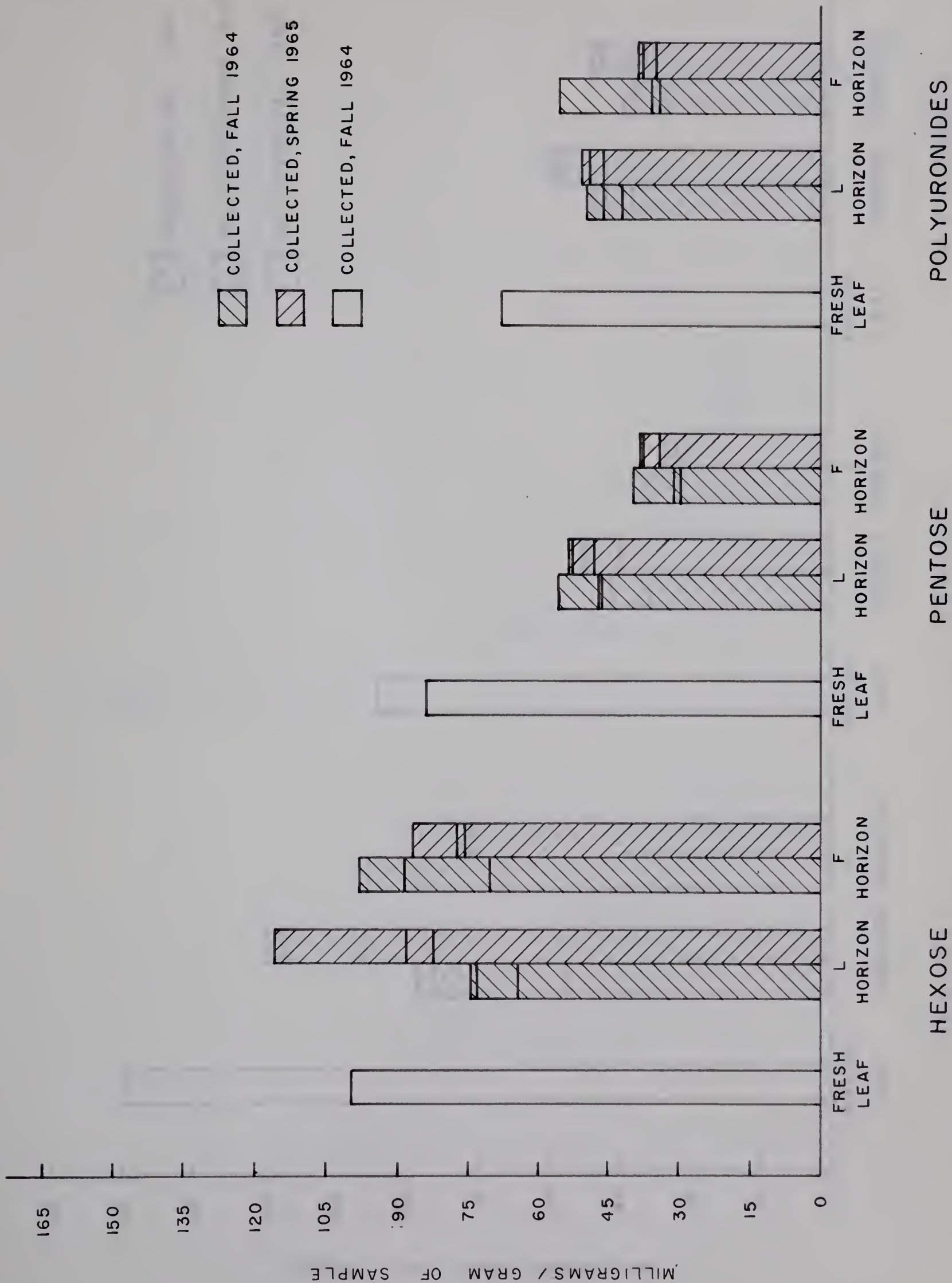Site 1 Polysaccharide Content of Organic Material

Figure 7

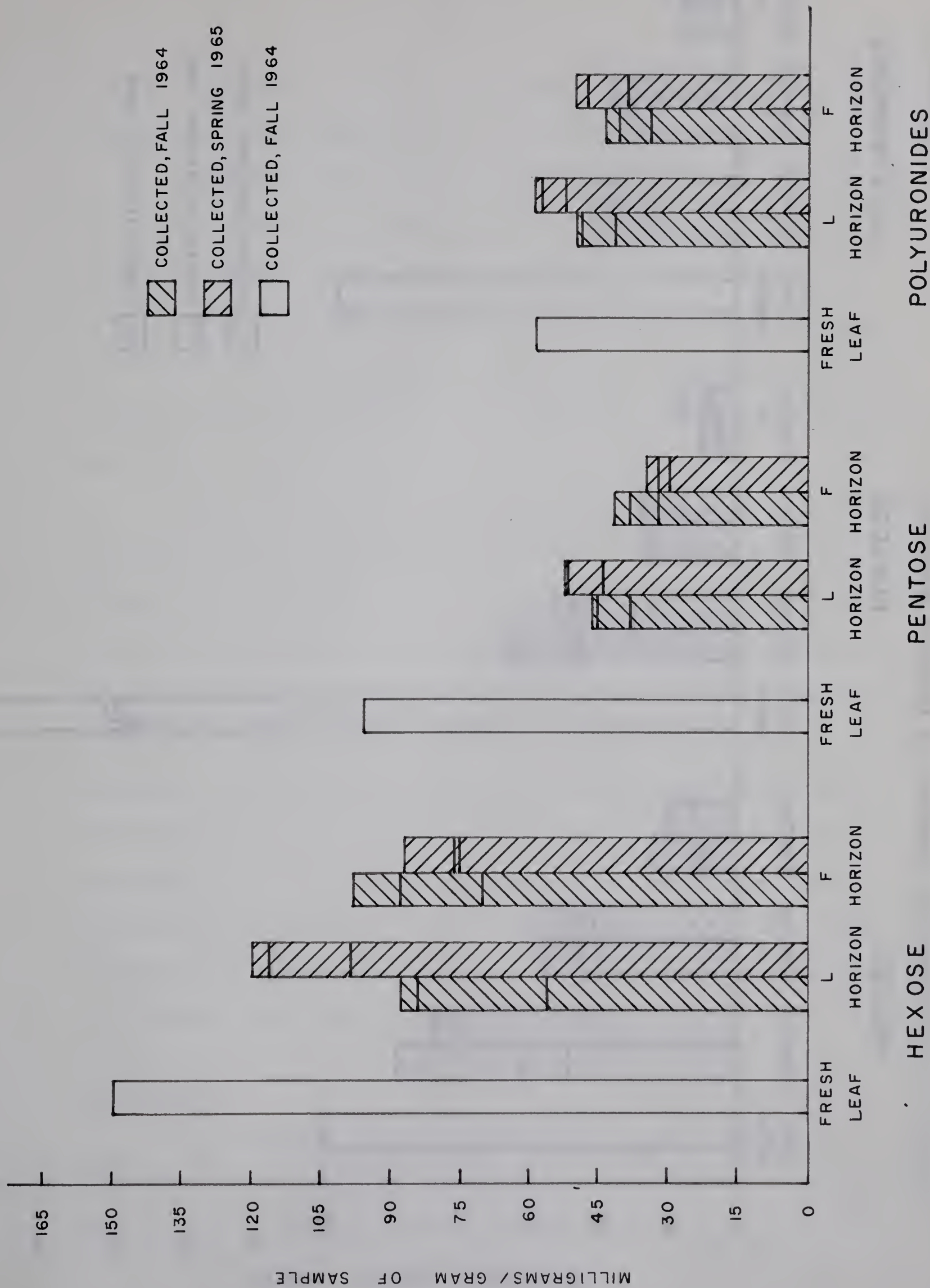Site 2   Polysaccharide Content of Organic Material   Figure 8

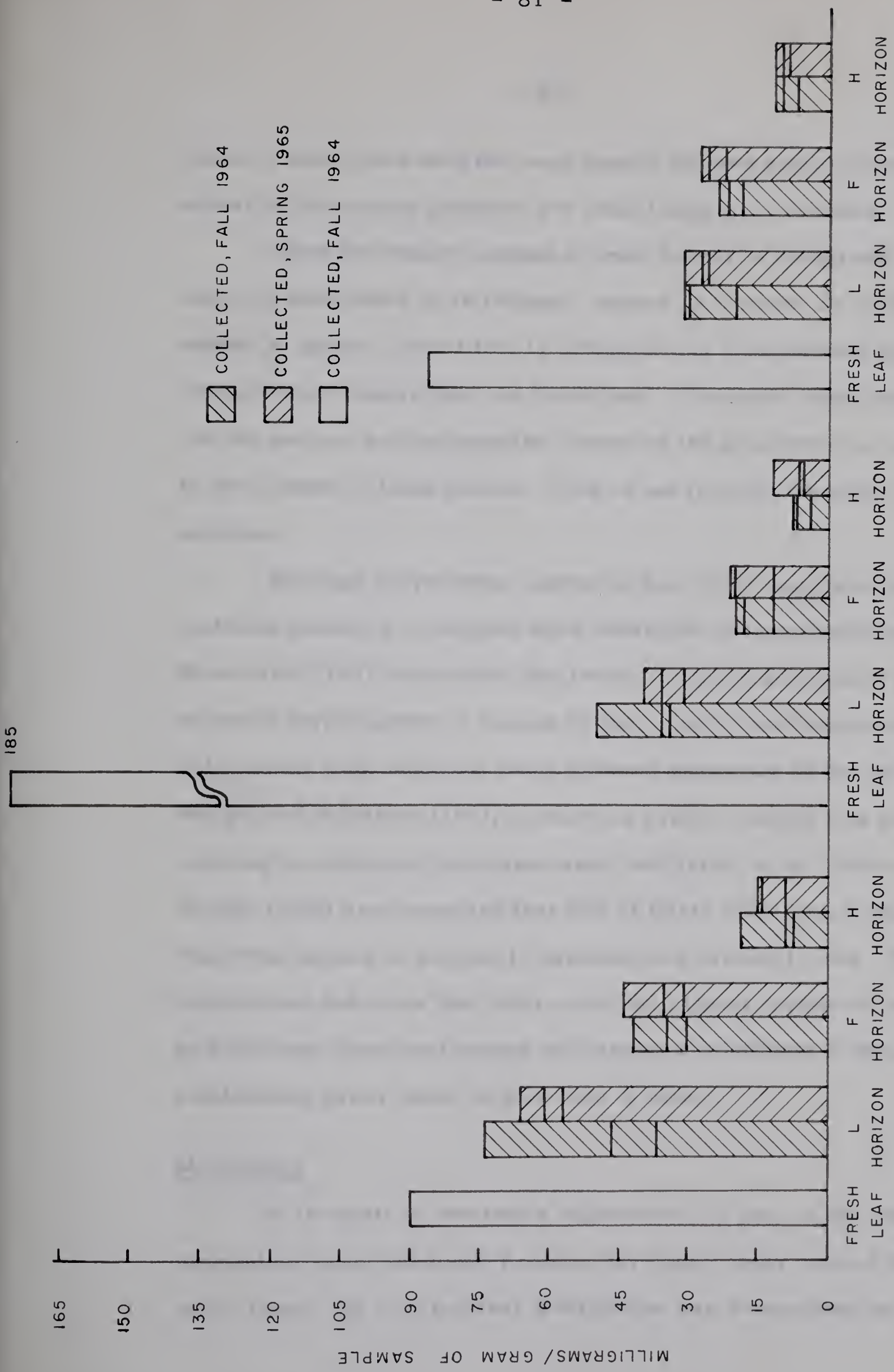Site 3   Polysaccharide Content of Organic Material   Figure 9

Site 4   Polysaccharide Content of Organic Material

Figure 10

Site 5   Polysaccharide Content of Organic Material

Figure 11

which is associated with the most poorly drained profile where the winter accumulation products are least likely to be leached.

When the hexose content of fresh leaves is compared, the order of dominance is as follows: spruce $>$ balsam $>$ pine $>$ aspen $>$ grass. Pine litter is unique in that it is the only litter to contain more hexose than the fresh leaf. The same trend holds true for the pentose and polyuronide content of the pine litter as compared to the content in fresh leaves. This is not true for the other vegetative species.

The high polyuronide content of pine litter suggests that this material produces a leachate most favorable to sesquioxide movement. Bloomfield (1957) states that the reduction of and subsequent solubilization of ferric oxides is caused by the action of carboxylic acids and polyphenols with reduction being affected primarily by the polyphenols. Wright and Schnitzer (1963) produced a profile similar to a podzol by leaching a column of calcareous sand with fulvic acid. Stobbe and Wright (1959) have reported that 60% of fulvic acids are composed of functional groups of carboxyl, hydroxyl and carbonyl units. This information indicates that litters with the highest content of carboxyl and hydroxyl functional groups will produce an effluent of the greatest solubilizing power which in this case is pine.

Mineralogy

In an effort to determine differences, if any, in the clay mineralogy associated with profiles developed under each of the vegetative types, the clay mineral distribution was determined by the use

of X-ray, D. T. A., surface area, cation exchange and total ele-
mental analyses techniques.

The data are presented in Table IX. Data for cation exchange
capacities and surface areas show a very good correlation. The Ae
of the profiles have a very low exchange capacity and surface area
and indicate a preferential movement of the montmorillonite down-
ward in the sola. The translocation from the Ae is greatest at Sites
3 and 4 (aspen and spruce vegetation respectively) where the mont-
morillonite content, as calculated from the surface area, is less
than 10 per cent. A preferential movement of lower intensity is also
apparent at Site 2 (pine vegetation). Surface area values of the clay
fraction of profiles at Sites 1 and 5 indicate that there has been little
movement of fine clays. Grossman et al (1959) state expanding lattice
clays disperse and move through the soil more easily than non-expand-
ing lattice clays.

Elemental analysis for clays (Table IX) shows an accumulation
of illite in the surface horizons of the profile formed under the aspen
vegetation (site 3) which may result from the preferential movement
of montmorillonite. The content of illite is calculated from the K_2O
content using a factor of 10 as suggested by Mehra and Jackson (1959).
The trend of decreasing illite content downward in the profile is not
evident in the profiles at Sites 2 and 4 (pine and spruce vegetation
respectively). The profiles at Sites 1 and 5 (balsam and grass
respectively) show similar contents of both montmorillonite and illite
in all horizons. The concomitant increase in montmorillonite and
illite content with depth in the profile at Sites 2 and 4 suggest similar

TABLE IX (a)

CLAY MINERAL ANALYSIS

Horizon	Total C.E.C. me./100 g.	Surface area m.sq./g.	% Montmorillonite	% K_2O	% Illite	Chlorite*	Quartz and Kaolinite*
Site 1	Gleyed Carbonated Dark Gray						
Bkgj	32.2	203	19	2.75	27	+	++
BCkgj	31.8	210	20	3.06	30	+	++
Ckgjl	28.4	193	18	3.14	31	++	+
Site 2	Bisequa Gray Wooded						
Ae1	30.9	143	14	2.40	24	+	+++
Bfj	26.9	148	14	2.49	25	++	+++
Ae2	29.2	179	17	2.69	27	+	++
Bt	37.6	250	24	2.74	27	+	+
Site 3	Orthic Gray Wooded						
Ae	18.0	104	10	2.94	29	++	+++
AB	33.4	240	23	2.66	27	++	+++
Bt1	37.0	218	21	2.48	25	+	++
Bt2	42.4	414	40	2.50	25	+	+
BC	41.4	319	31	2.55	25	+	+

*Expressed as relative quantities within each profile
+ low   ++ medium   +++ high

TABLE IX (b)

CLAY MINERAL ANALYSIS

Horizon	Total C.E.C. me./100 g.	Surface area m. sq./g.	% Montmor- illonite	% K_2O	% Illite	Chlorite*	Quartz and Kaolinite*
Site 4 Solodic Gray Wooded							
Ae	11.4	101	10	3.02	30	++	++
AB	15.9	166	16	3.18	32	++	++
Btnj1	29.5	353	34	3.51	35	+++	++
Btnj2	33.2	384	37	3.48	35	+	++
BC	30.6	360	35	3.62	36	+	++
C	28.8	329	32	3.61	36	++	+
Site 5 Dark Gray							
AB	28.9	330	32	3.53	35	++	++
Btj	29.3	344	33	3.69	37	+	++
BC	29.8	338	32	3.49	35	+	++
IIC	29.2	323	31	3.71	37	+	+

* Expressed as relative quantities within each profile
+ low   ++ medium   +++ high

rates of translocation.

X-ray analysis: The X-ray patterns (Figures 12 - 16) of the profile sampled under the balsam vegetation (Site 1) indicate a high degree of chlorite-montmorillonite interstratification which appears to be predominantly chlorite. This is indicated by the presence of a shoulder at 6.4 degrees on the X-ray diffraction pattern for the glyco-lated samples and the presence of a peak at the same point on the pattern from the heated samples. The diffraction pattern of the heated sample exhibits a plateau which extends from 6.4 degrees to 8.9 degrees. This is indicative of chlorite-montmorillonite mixed layer arrangement.

According to Weaver (1958), montmorillonite-illite and mont-morillonite-chlorite mixed layers are common. The mixed layer clays can usually be identified after the samples have been glycolated. If the peak does not shift completely to 5.2 degrees, there are some non-montmorillonite layers present, either illite or chlorite. Heating to 550° C. causes a peak shift between 8.8 and 9.3 degrees and indi-cates the non-expanding layers to be 8.8 degree material, usually illite. If the peak does not shift completely to 8.8 degrees, some chlorite layers are probably present and the clay is likely a chlorite-montmor-illonite intergrowth. The presence of distinct peaks for X-ray diffrac-tion patterns of the clay fraction in the parent material sample of the profile at Site 1, indicates that interlayering is discrete rather than random.

X-ray diffraction patterns of the clay fraction from the profile at Site 2 indicate the presence of a large amount of mixed layering with
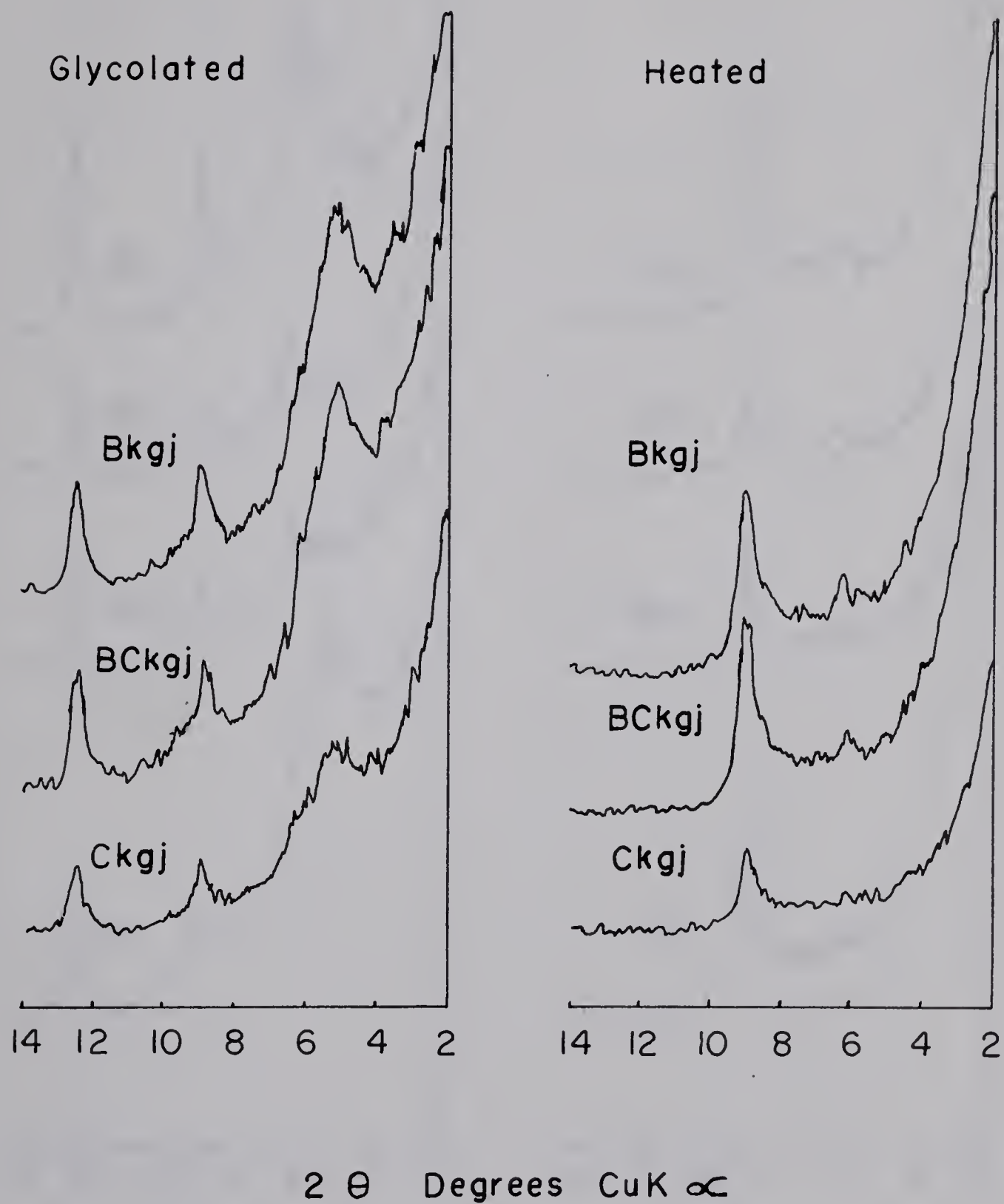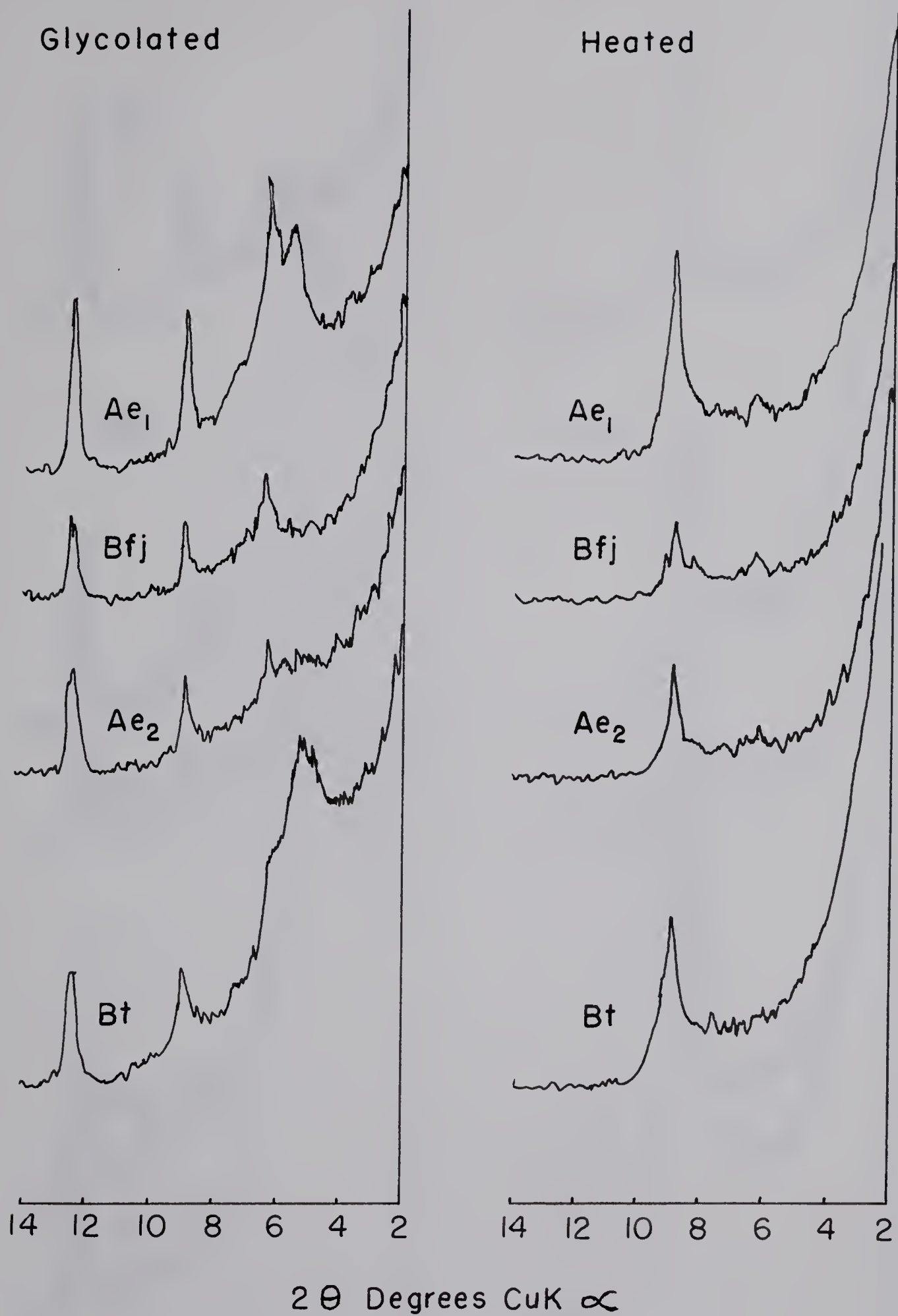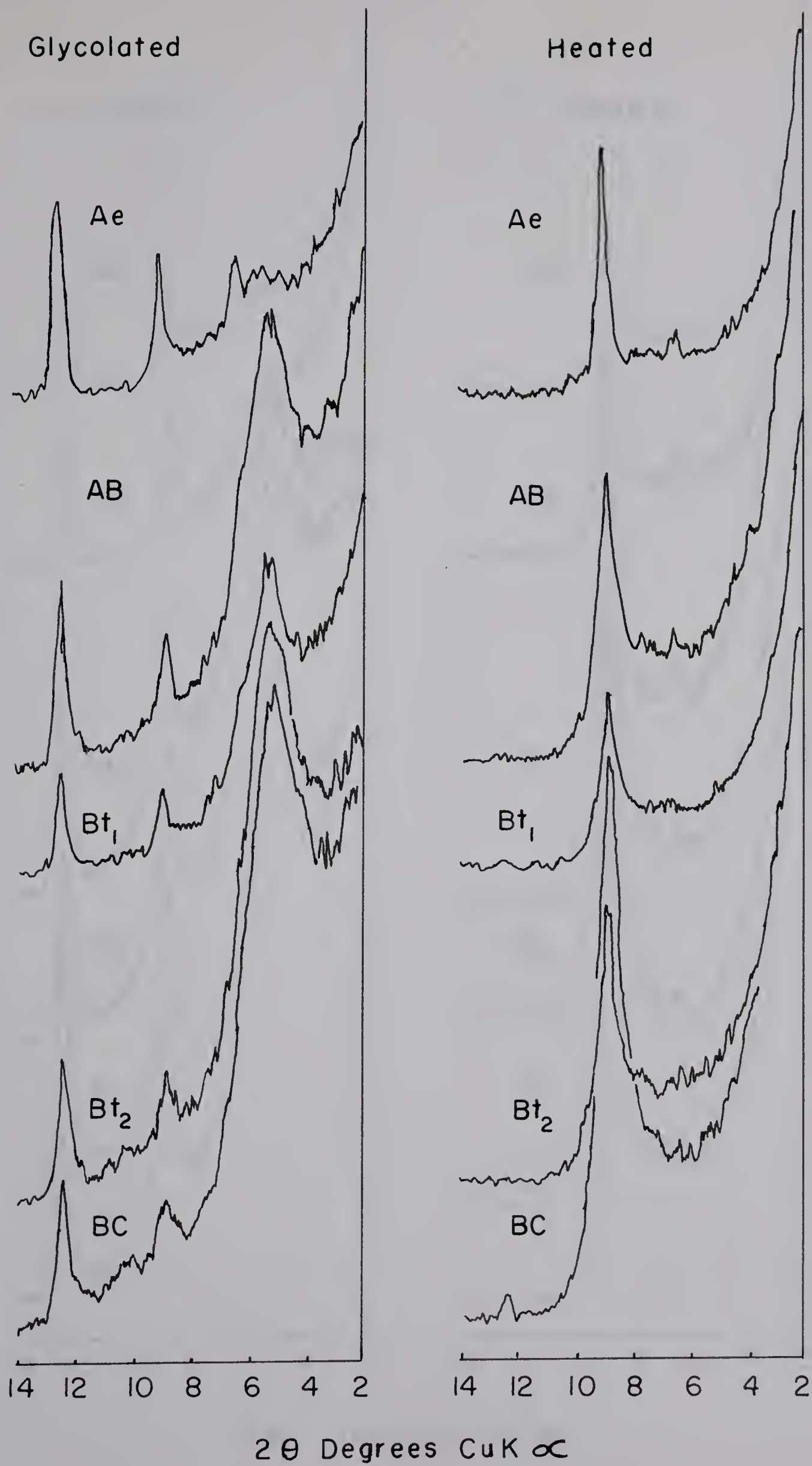
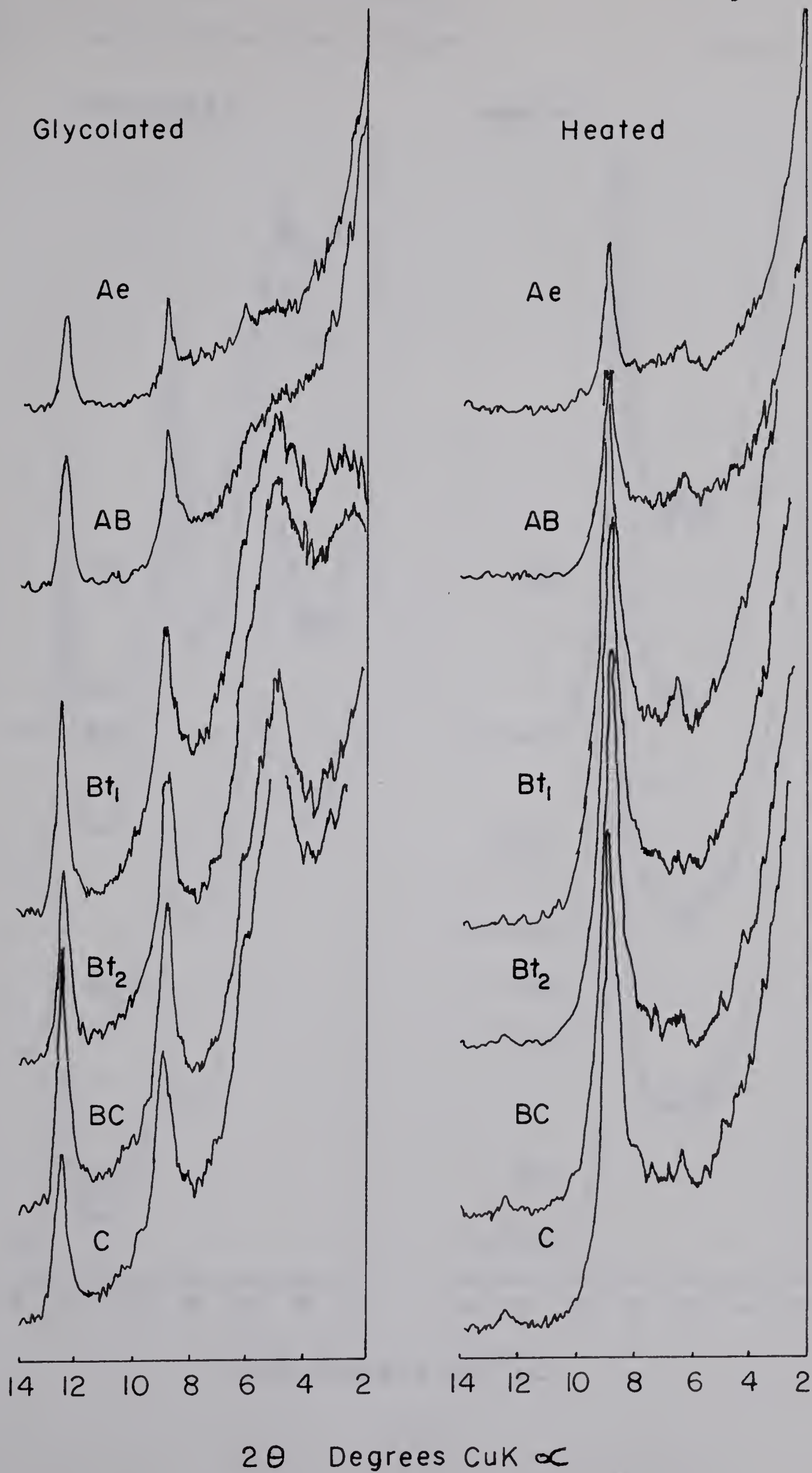Site 1   X-ray Diffraction Patterns   Figure 12

Glycolated

Bkgj

BCkgj

Ckgj

Heated

Bkgj

BCkgj

Ckgj

14 12 10 8 6 4 2   14 12 10 8 6 4 2

2 θ   Degrees CuK ∝

Site 2   X-ray Diffraction Patterns   Figure 13

Site 3 X-ray Diffraction Patterns   Figure 14

Glycolated

Heated

Ae

AB

Bt₁

Bt₂

BC

2θ Degrees CuKα

Site 4   X-ray Diffraction Patterns   Figure 15

Glycolated   Heated

Ae   Ae

AB   AB

Bt₁   Bt₁

Bt₂   Bt₂

BC   BC

C   C

14 12 10   8   6   4   2   14 12 10   8   6   4   2

2θ   Degrees CuK ∝

Site 5 X-ray Diffraction Patterns

Figure 16

Glycolated

Heated
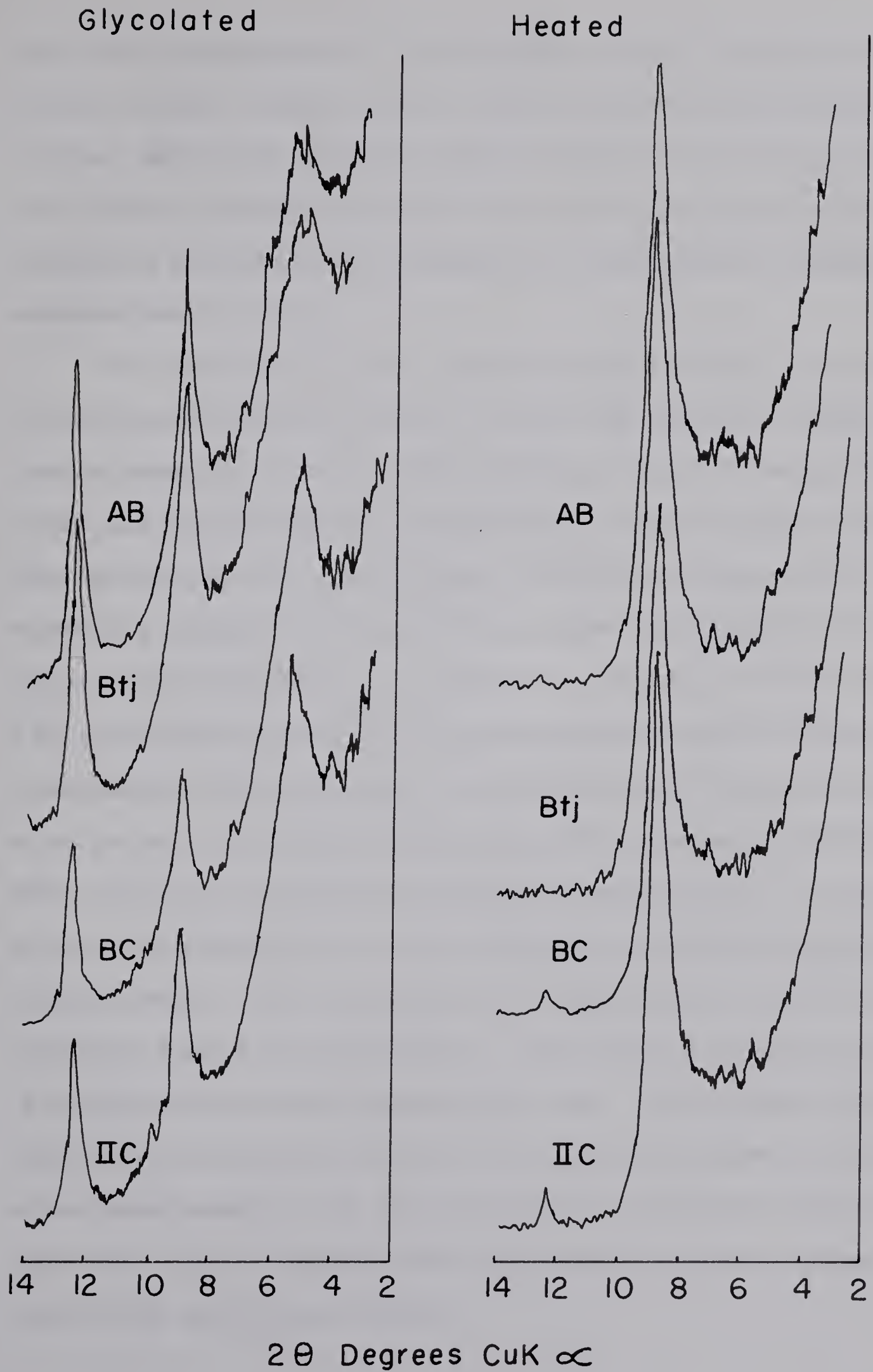
AB

Btj

BC

IIC

AB

Btj

BC

IIC

2θ Degrees CuK α

very little chlorite present. The maximum content of chlorite, although present in minor amounts, in this profile is concentrated in the Bfj horizon. The X-ray diffraction patterns of the Bt clay fraction of this profile shows a definite increase in the amount of montmorillonite present and substantiates the conclusion that preferential leaching of montmorillonite occurs.

The clay fraction of the samples collected at Site 3 produces an X-ray diffraction pattern indicative of very high amounts of mixed layered materials in the Ae with decreasing amounts downward in the profile and suggests that the interlayering may result at least in part from weathering of the clay minerals. This being the case, the weathering conditions are more intense at Site 2 as indicated by the higher content of mixed layered minerals at this site. At Sites 3 and 4 the preferential movement of montmorillonite is indicated by the accumulation of montmorillonite in the Bt horizon. The clay fraction of the Ae and AB horizons of the profile at Site 4 produces an X-ray diffraction pattern which shows intense interstratification, as indicated by the broad plateau from 4.9 to 8.9 degrees in the heated and glycolated sample patterns. The remaining X-ray diffraction patterns of samples from Sites 4 and 5 are very similar. They contain a high percentage of montmorillonite with some mixed layering. The samples contain very little interstratified chlorite as indicated by the slope of the graph of the heated sample. The more perpendicular the slope at the lower angle side of the 8.9 degree peak, the greater the content of montmoril-lonite in the mixed layer material.
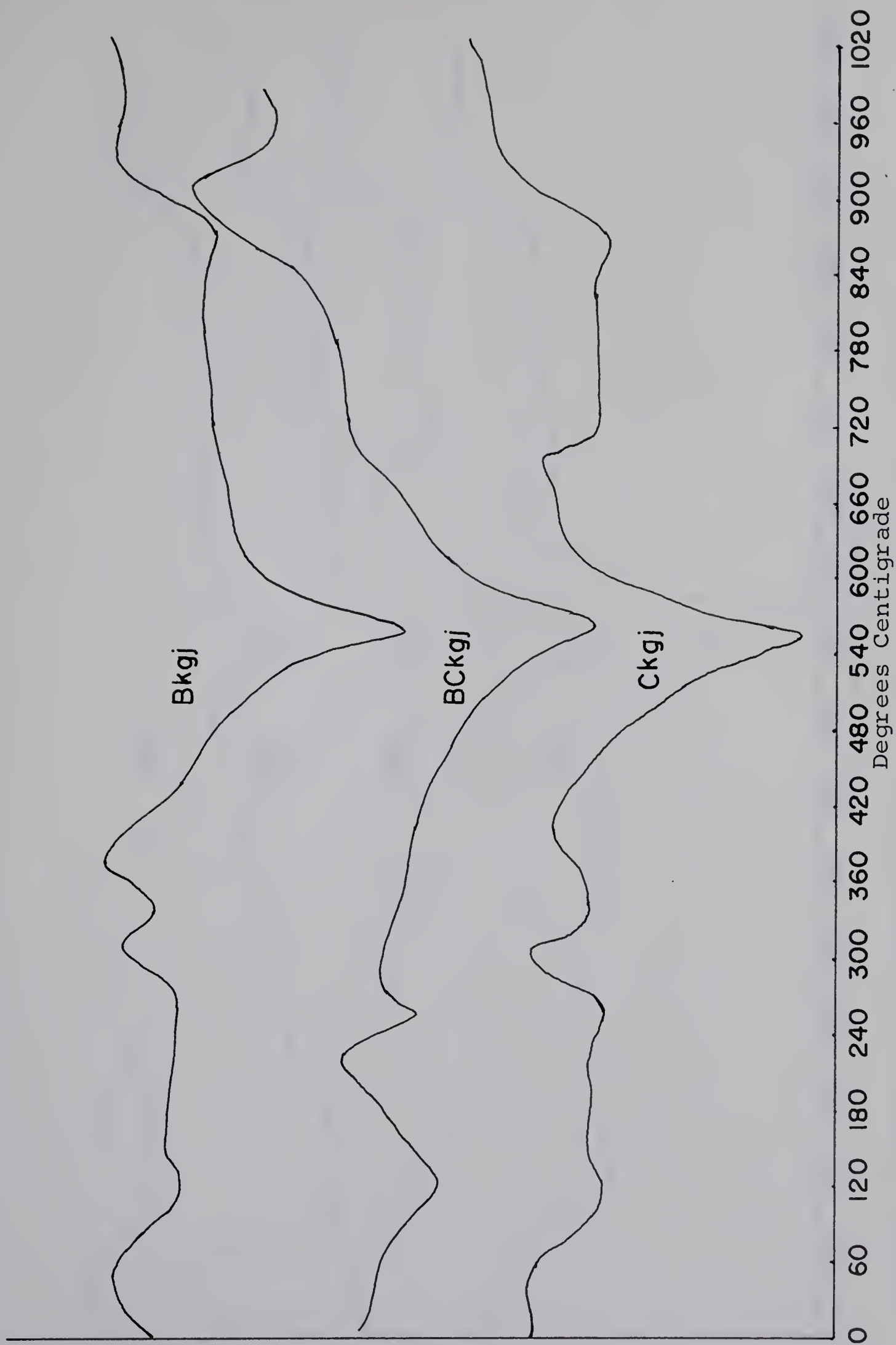
Differential thermal analysis (Figures 17 - 21) is used to determine the nature and composition of clay minerals in this study. Iron oxides are indicated by the presence of an endothermic peak which occurs between 258° C. and 360° C. generally peaking at 328° C. Organic matter is indicated by the presence of an exothermic peak in the same area. Illite is indicated by an endothermic peak in the range of 500° C. to 600° C. generally peaking at 560° C. Normal montmorillonite is indicated by the degree of intensity of the water of hydration peak and endothermal peaks in the range 600° C. to 700° C. generally peaking at 670° C. and between 850° C. and 950° C. Kaolinite produces an endothermal peak between 455° C. and 625° C. peaking near 560° C. Chlorite produces an endothermic peak ranging from 520° C. to 680° C. and peaking near 610° C. and an exothermic peak near 870° C. Dolomitic material produces endothermic peaks in the range $760 - 825^\circ$ C. peaking near 780° C. and 810° C. to 920° C. peaking near 855° C.

Samples from the profile at Site 1 under the balsam poplar indicate the presence of both iron and organic matter. The organic matter is bound to the clay and was not removed in the pretreatment with H_2O_2. The broad plateau between the temperatures of 700° C. and 868° C. is an indication of dolomitic material as well as chlorite. The presence of the endothermic peak at 330° C. in the Bfj horizon of the profile collected under the pine vegetation suggest the presence of Fe_2O_3. The increase in intensity of the peak, resulting from water of hydration, with depth in the sola at Sites 3 and 4 indicates an increase in content of montmorillonite and further suggests the preferential movement of montmorillonite. The patterns produced from the profile

Bkgj

BCkgj

Ckgj

Degrees Centigrade

0 60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020
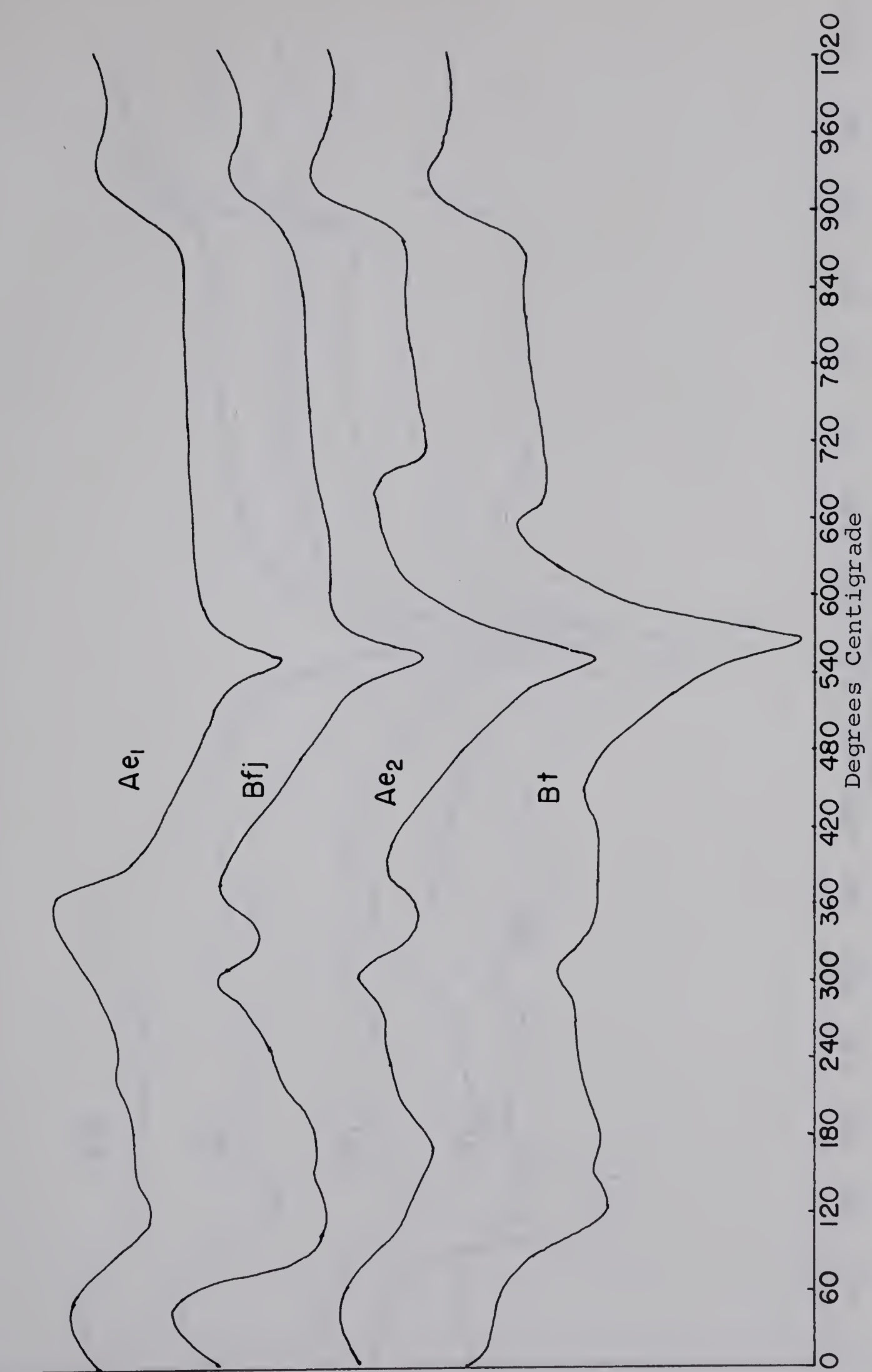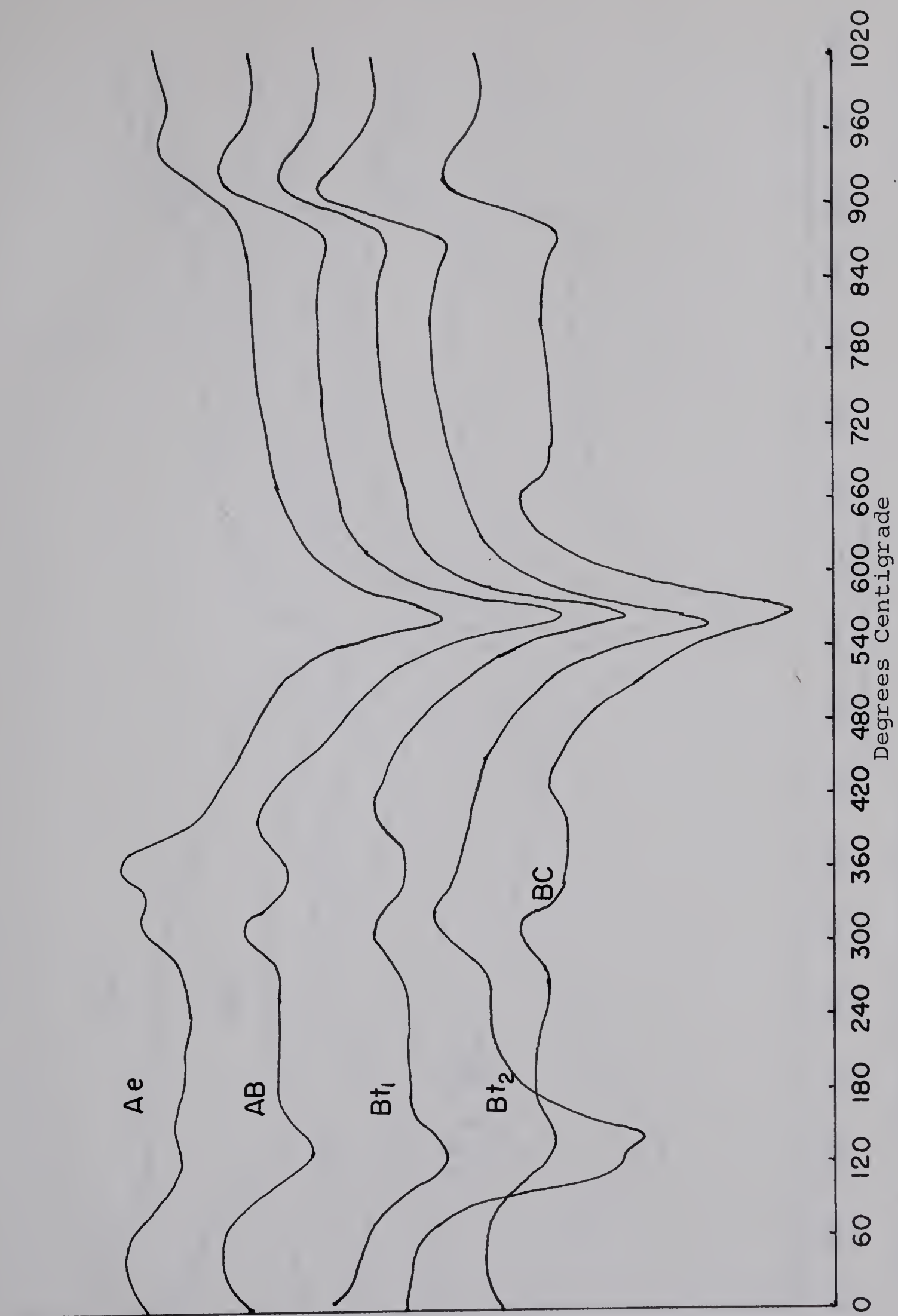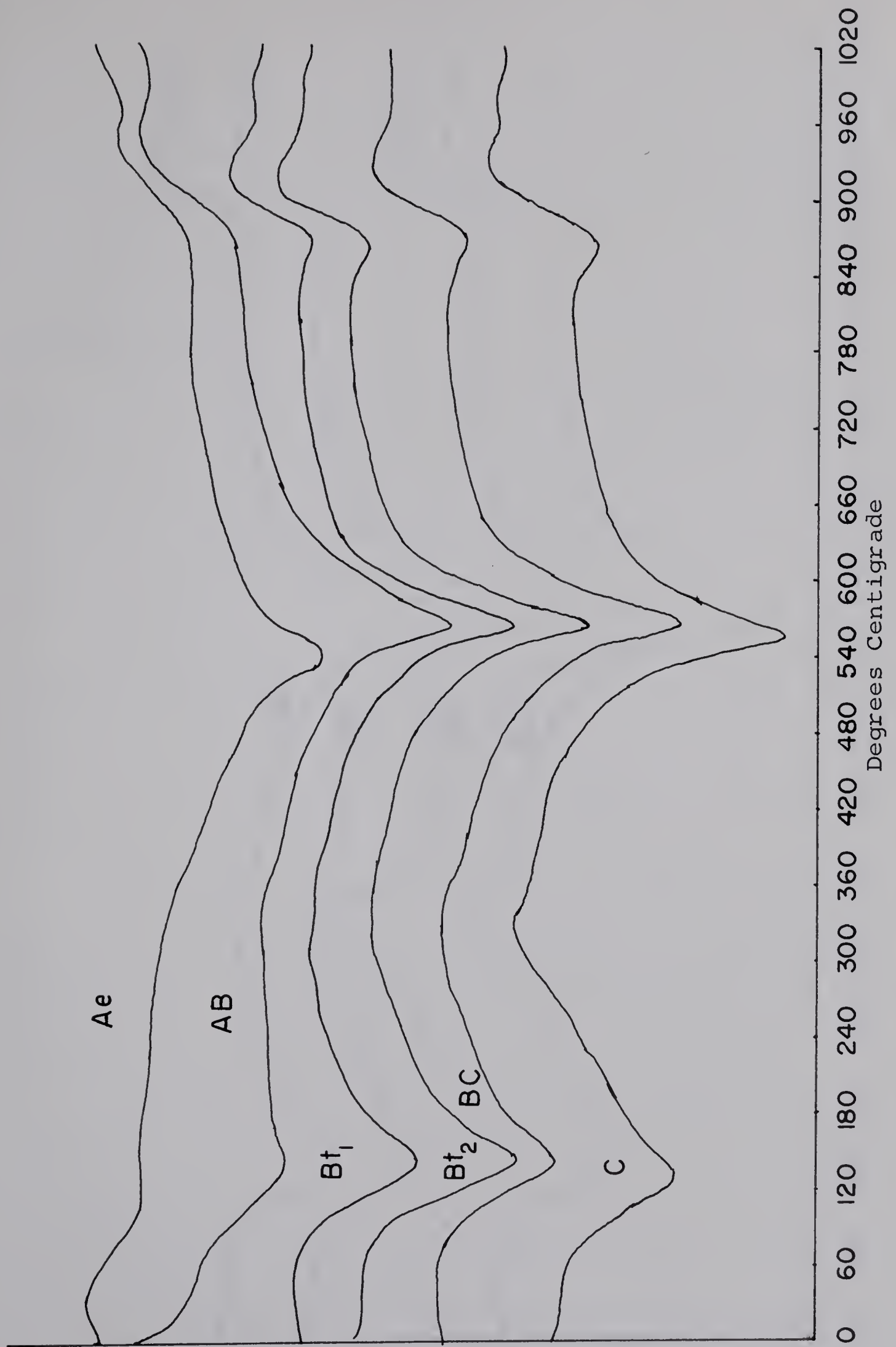
Site 1   Differential Thermographs   Figure 17

Site 2   Differential Thermographs

Figure 18

Site 3   Differential Thermographs   Figure 19
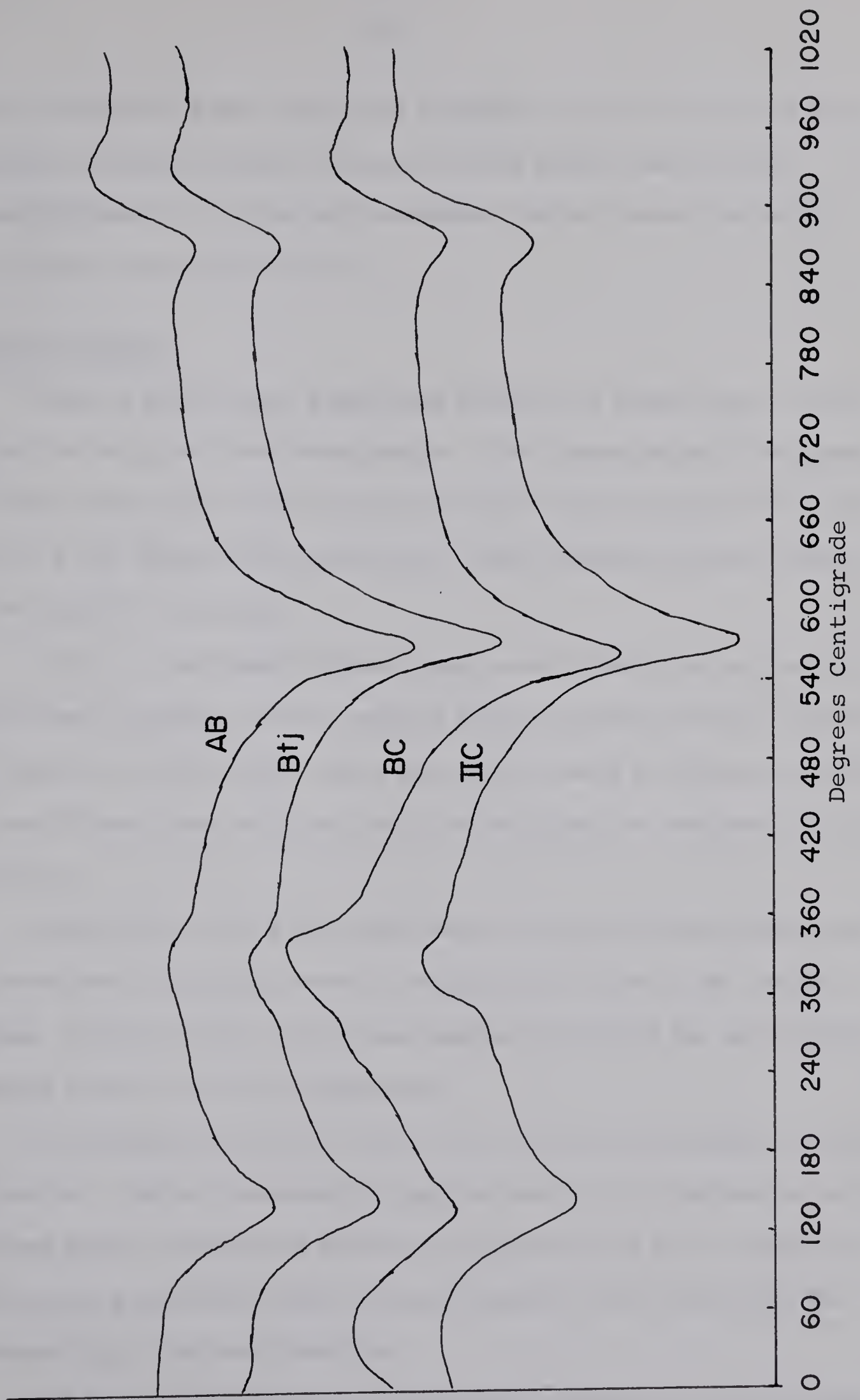
Site 4   Differential Thermographs

Figure 20

AB

Btj

BC

IIC

Degrees Centigrade

0 60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020

Site 5 Differential Thermographs

Figure 21

collected under the grass vegetation suggests that there may have been a leaching of organic matter downward in the profile but this and mechanical analysis are the only indication that any translocation of material has occurred at this site.

Biological Studies

Table X shows some significant differences which appear in the total microbiological count examination. The counts shown here appear high when compared to total counts reported in other studies but is the result of a two week incubation period at field capacity and calculation is based on oven dry weight.

There is a noticeably higher fungi count in the pine and spruce F horizons which agrees with the work of Gray and Taylor (1935) and probably results from the higher lignin and resin content of this leaf material. The low pH associated with the pine litter explains the dominance of fungi at this site.

At the spruce and aspen sites there is a high actinomycetes count. The low values of actinomycetes at the pine site is due to the low pH, whereas, under the grass and balsam poplar vegetation the near neutral pH values favors a bacterial population.

The values presented in Table XI report the microscopic examination results. There is generally a high percentage of arthrobacter in the aspen and poplar vegetations with this organism being absent under pine. The bacterial population under the pine vegetation was dominantly the rod-shaped spore forming bacillus.

The major differences in microbiology explains, to some extent, the differences in decomposition of the various litters. The formation

TABLE X

PLATE COUNTS

Sample	Total* x 10^5	Actinomycetes* x 10^5	Fungi* x 10^5
Balsam Poplar	330	10	0
Balsam Poplar	320	10	0
Pine	310	32	140
Pine	260	30	140
Aspen Poplar	140	60	0
Aspen Poplar	140	62	0
White Spruce	570	370	160
White Spruce	600	250	100
Grass	240	35	10
Grass	260	36	10

*Expressed as numbers per gram of oven dry sample.

TABLE XI

DISTRIBUTION OF ORGANISMS SEPARATED

Sample	Actino-mycetes No.	%	Arthro-bacter No.	%	Bacillus Chain No.	%	Rod No.	%	Diploid No.	%	Total No.	%	Coccus No.	%	Fungi No.	%	Total No.
Balsam Poplar	3	8	15	42	10	28	7	19	0	0	17	47	0	0	0	0	36
Pine	0	0	0	0	0	0	7	41	1	6	8	47	1	6	8	47	17
Aspen Poplar	4	12	17	50	2	6	8	24	3	8	13	34	0	0	0	0	34
White Spruce	6	12	5	10	5	10	14	29	3	6	22	44	1	2	15	31	49
Grass	12	20	12	20	9	31	16	26	0	0	35	57	1	1	1	1	61

of an Ah horizon is generally associated with grass and balsam poplar vegetations which is the case in this study. Also associated with this is a predominance of bacteria in the microflora of the litter indicating bacteria to be the organism responsible for the production of stable high molecular weight humic acids and thus an Ah horizon.

Pine vegetation is generally associated with strong podzolization processes. In this study fungi is the dominant organism associated with this vegetation indicating the organism to be responsible for the production of the short chain, highly carboxylated materials generally considered responsible for a major portion of the mineral weathering and the subsequent translocation. Spruce litter also has a large fungal population.

Aspen poplar and spruce litter are intermediate in pH between the highly acid pine and the near neutral grass and balsam litters. Aspen poplar and spruce in Alberta are commonly associated with podzolization which is dominantly clay translocation rather than weathering. This may be to some extent the result of the decomposition products of the microfloral population which in this case is dominantly actinomycetes.

V. CONCLUSIONS

Examination of data from this study indicates that the different vegetative types have a definite and different effect on the pedological development of the soil sola. The different vegetative types produce many differences in the sola developed from parent material similar in mineralogy and chemistry.

The different litters produced have a different morphology. The F horizon of the pine litter exhibits a very distinct leaf structure and appears to exfoliate rather than decompose completely. This exfoliation probably results in the production of low molecular weight materials (Stobbe and Wright, 1959). In the F horizon of the litter found under aspen and balsam, there is only a weak leaf structure present in the form of small broken particles. The grass vegetation has only a thin fluffy organic mat overlying the Ah horizon. The morphology of the F horizon of spruce litter is intermediate in development between pine and aspen. An H and Ah horizon under balsam and grass vegetation is noticeably absent under pine and spruce. Aspen litter has developed a very shallow H horizon.

Differences in the microbiological populations may be related to the development of different morphology. Fungi dominate the microflora of pine litter and are present in large numbers in the spruce litter. Actinomycetes are present in the largest numbers in the litter of aspen and spruce. Balsam and grass microfloral populations are dominated by bacteria. The pH of balsam and grass litter is near neutrality; pine litter is highly acid (pH 4.8) and aspen and

spruce litter is intermediate. This indicates both pH and nature of the fresh leaf are effective in determining the microbiological populations.

The decomposition of the fresh leaves by the biological population is similar in all litters. There is a decrease in carbon content, generally an increase in nitrogen content, a decrease in C/N ratio, an increase in ash content, and an increase in cation exchange capacity with increased decomposition. The metallic cations of magnesium and potassium do not increase in content with depth in the litter, whereas, iron does. Calcium generally accumulates in the leaf litter but not with increasing depth. Potassium is present in the highest content in balsam and aspen leaves but is rapidly leached from the litter, thus producing an effluent high in potassium.

The polysaccharide data of the leaf litters show pine to have the highest content of this material. Normal rainfall leaching through the litter produces an effluent high in materials with associated hydroxyl and carboxyl functional groups. The resulting low pH combined with the low metallic ion content (Figure 3) in the effluent results in an increase in exchange acidity which dominates the exchange complex of the Ae and Bfj horizons. The more intensive weathering ability of the effluent at Sites 2 and 4 (pine and spruce vegetation respectively) is exhibited by the decrease in per cent of exchangeable calcium in the profile as compared to Sites 1, 3 and 5 (balsam, aspen and grass respectively). The increase in per cent exchangeable calcium with depth at Site 2 is indicative of the

mobilizing ability of the effluent from pine litter.

Mechanical analysis indicates clay translocation at Sites 2, 3, 4 and 5. X-ray, differential thermal analysis, cation exchange, surface area and elemental analysis indicate clay translocation at Sites 2, 3 and 4, with differences evident for the various vegetative types. At Site 3 montmorillonite is moved preferentially resulting in an enrichment of illite in the eluviated Ae and AB horizons. Montmorillonite also moves to a greater extent under aspen than under pine and spruce. At Sites 2 and 4 montmorillonite and illite move concomitantly. The greater weathering ability of the pine and spruce litter effluent is indicated by the presence of higher content of mixed layered chlorite-montmorillonite in the Ae horizon of the profiles at Sites 2 and 4.

Amorphous iron measured by the oxalate method shows an increase in the Bfj horizon of Site 2 and the Bt horizon of Site 4 that is absent in the profiles at Sites 1, 3 and 5. There is no indication of amorphous aluminum oxide movement in any of the profiles.

Iron translocation is associated with biological population and calcium content of the leaf litter and the soil sola exchange complex. In the profiles where iron movement occurred (Sites 2 and 4), the calcium content of the leaf and leaf litter is low. As previously mentioned, fungal populations are highest and per cent exchangeable calcium lowest at Sites 2 and 4 as compared to the other sites. All factors combine to create a low calcium to iron ratio and a condition most suitable to podzolization.

In conclusion, it may be stated that the development of the soil sola is very closely linked to the vegetative types and its associated biological population. The intensity of profile development for the sites studied may be arranged as Bisequa Gray Wooded (Site 2) > Solodic Gray Wooded (Site 4) > Orthic Gray Wooded (Site 3) > Dark Gray (Site 5) > Gleyed Carbonated Dark Gray (Site 1).

VI. BIBLIOGRAPHY

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